



Carnegie Mellon University

Undergraduate Catalog

2023-2024

College of Engineering

College of Fine Arts

Dietrich College of Humanities and Social Sciences

Heinz College of Information Systems and Public Policy

Mellon College of Science

School of Computer Science

Tepper School of Business

Carnegie Mellon University in Qatar

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2023-2024 Undergraduate Catalog

Carnegie Mellon University is accredited by the Middle States Commission on Higher Education. The university is authorized to operate in several states.
www.cmu.edu (<http://www.cmu.edu>)

Carnegie Mellon University's Undergraduate Catalog is an annual publication that details academic programs and degrees offered, course descriptions, and university policies and services.

While information in this catalog is current as of August 2023, it is subject to change throughout the academic year. Students should consult with their academic department for the most up-to-date information about program requirements. Members of the campus community may direct catalog changes or inquiries to catalog@andrew.cmu.edu. Note that once the PDF of the catalog is final and archived, changes can only be made to the online version.

The next catalog will be published in August 2024; in the interim, new courses will be displayed in the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>), which is published in November and April each year.

Policy Statement

Carnegie Mellon University does not discriminate in admission, employment, or administration of its programs or activities on the basis of race, color, national origin, sex, handicap or disability, age, sexual orientation, gender identity, religion, creed, ancestry, belief, veteran status, or genetic information. Furthermore, Carnegie Mellon University does not discriminate and is required not to discriminate in violation of federal, state, or local laws or executive orders.

Inquiries concerning the application of and compliance with this statement should be directed to the Office for Institutional Equity and Title IX, Carnegie Mellon University, 5000 Forbes Avenue, Pittsburgh, PA 15213, telephone 412-268-7125.

Obtain general information about Carnegie Mellon University by calling 412-268-2000.

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About CMU

Carnegie Mellon is a private, internationally ranked (<https://www.cmu.edu/about/rankings.html>) research university with programs in areas ranging from science, technology and business, to public policy, the humanities and the arts. More than 15,000 students in the university's seven schools and colleges benefit from a small student-to-faculty ratio and an education characterized by its focus on creating and implementing solutions for real problems, interdisciplinary collaboration and innovation.

Undergraduate students can pursue majors in six of the university's seven colleges: the College of Engineering, the College of Fine Arts, the Tepper School's business administration program, the Dietrich College of Humanities and Social Sciences, the Mellon College of Science, and the School of Computer Science.

CMU is positioned like never before to meet the challenges of the 21st century. At the intersection of technology and humanity, CMU research, innovation and creativity will continue to guide our future as a world-class university.

As outlined in the Strategic Plan 2025 (<http://www.cmu.edu/strategic-plan/>), the university will focus on advancing the individual student experience, the broader Carnegie Mellon community experience, and the social impact of Carnegie Mellon throughout the world.

Take a closer look at CMU (p. 7).

Vision & Mission

Vision

Carnegie Mellon University will have a transformative impact on society through continual innovation in education, research, creativity, and entrepreneurship.

Mission

To create a transformative educational experience for students focused on deep disciplinary knowledge; problem solving; leadership, communication, and interpersonal skills; and personal health and well-being.

To cultivate a transformative university community committed to (a) attracting and retaining diverse, world-class talent; (b) creating a collaborative environment open to the free exchange of ideas, where research, creativity, innovation, and entrepreneurship can flourish; and (c) ensuring individuals can achieve their full potential.

To impact society in a transformative way — regionally, nationally, and globally — by engaging with partners outside the traditional borders of the university campus.

Look at Carnegie Mellon

CMU's History

In a letter written in 1900, industrialist and philanthropist Andrew Carnegie offered to give the city of Pittsburgh \$1 million in bonds to found a technical institute. The city provided 32 acres of land near Schenley Park, and the institution became known as the Carnegie Technical Schools. According to Carnegie's plans, the institution would train the sons and daughters of working-class families in five schools: Science and Technology, to train draftsmen and engineer's assistants; Fine and Applied Arts, for designers and art workers; Apprentices and Journeymen, for mechanics in manufacturing and construction; and Margaret Morrison Carnegie College, for home economists or secretaries. Within two decades, the Carnegie Technical Schools offered bachelor's, master's and doctoral programs, and fittingly changed its name to the Carnegie Institute of Technology.

In 1967, the trustees of the Mellon Institute and the Carnegie Institute of Technology merged the two institutions and adopted the name Carnegie Mellon University. In 1968, Margaret Morrison Carnegie College closed and the university organized a new College of Humanities and Social Sciences. New graduate-level colleges and schools also flourished, including the Graduate School of Industrial Administration (GSIA), the Heinz College of Public Policy and Management, and the School of Computer Science. As time progressed, new research centers and institutes developed on and off campus in specialties ranging from art conservation to sustainable computing. In 2004, GSIA was renamed the Tepper School of Business after alumnus David A. Tepper.

Over time, the Carnegie Institute of Technology has developed from a regional, technical college into Carnegie Mellon University, a selective, international research university that ranks among the nation's best colleges.

more than 20 research partnerships such as Los Angeles, New York City, Washington, D.C., Portugal, and Africa.

A Unique Educational Experience

The university's diverse community, focus on strong student-faculty ties and commitment to education outside the classroom combine to create a learning environment that is as uniquely Carnegie Mellon as the Tartan plaid on the kilts of its bagpipers.

Carnegie Mellon strives for a campus culture that reflects a fundamental respect for different ways of living, working, and learning so every student has the opportunity to reach their potential.

A Carnegie Mellon education is marked by its strong focus on fundamental and versatile problem-solving skills in a specific discipline, but the university respects and values students' varied talents and interests that often span many specialties. Students can explore more than one field of study while developing the strong professional core that is the hallmark of a Carnegie Mellon education. The university encourages students to expand their thinking in new and exciting dimensions.

CMU's faculty conduct groundbreaking research, create new and exciting art, and contribute to a growing global scholastic community. They are continuously innovating, and the new knowledge they create and the methods they discover routinely benefit classroom learning. Research is a vital component of undergraduate education at Carnegie Mellon. Students can initiate projects of their own or become involved with existing ones on campus.

A Global Impact

In its 115 years, Carnegie Mellon has soared to national and international leadership in higher education and research. A birthplace of innovation since its founding, it continues to be known for innovation, for solving real-world problems and for interdisciplinary collaboration.

Its alumni can be found across the globe — from Tony Award winners to Nobel Prize and Turing Award winners, from CEOs to entrepreneurs, from professors to artists.

In the 2000s, in response to demand for expanded international educational opportunities, Carnegie Mellon began offering degree programs outside of Pittsburgh. Today its global presence includes campuses in Qatar and Silicon Valley, California, more than a dozen degree-granting locations, and

Undergraduate Admission

Kristina Wong Davis, Vice Provost for Enrollment Management & Dean of Admission

Gregory Edleman, Associate Dean, Director of Admission

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 Email: admission@andrew.cmu.edu
www.cmu.edu/admission (<http://www.cmu.edu/admission/>)

ADMISSION PHILOSOPHY

At Carnegie Mellon University, we select our first-year class from a large group of very qualified candidates. The majority of our applicants are admissible and could be successful at Carnegie Mellon. We use a variety of factors to select our first-year class from those admissible candidates. We don't use a calculation to arrive at our admitted class. Calculations can't take into account all of the factors we consider when making admission decisions. We treat every applicant as an individual, taking great care to make fair and thorough admission decisions in context.

ADMISSION CRITERIA

Our admission process is designed to select a highly talented, diverse undergraduate population with high aspirations who will succeed at Carnegie Mellon. If you're applying to academic programs, your high school performance will be a significant factor in our admission decision because it's the most meaningful indication of your motivation and abilities. We pay close attention to your curriculum rigor, the grades you've earned and the work you've accomplished. We're interested in seeing that you've challenged yourself within your secondary school environment. If you're applying to programs in the arts, your artistic performance will be either the main factor or a significant factor (depending on the program) in our admission decision.

Standardized test scores add to our knowledge of your preparation, but we don't make decisions on the basis of test scores alone. SAT and ACT scores are completely optional, but if you choose to provide them, they'll work with your secondary school record to make up the academic portion of your evaluation. SAT Subject Tests are neither required nor recommended and aren't considered in our admission process.

Your non-academic interests, including extracurricular involvement, part-time jobs, family commitments, hobbies and community engagement play a very important role in the admission process. We also consider collaboration, perseverance, passion, advocacy for others and self-direction when making admission decisions. We're interested in students who can be successful at Carnegie Mellon while fully engaging in the university community. Because we want to have a sense of who you are as a person, we look closely at your Common Application essay, your short answer questions, your secondary school counselor's evaluation and your secondary school teacher's recommendation. By looking at this non-academic information, we develop a sense of your personality, motivation and responsibility.

We don't consider demonstrated interest in our admission process. Demonstrated interest is a term used in undergraduate admission that describes the ways in which a prospective student shows a college that they're interested by visiting campus and submitting additional materials that aren't required in the application. As a result, we don't consider a campus visit or communication with the Office of Admission or other members of the Carnegie Mellon community when making admission decisions.

Carnegie Mellon doesn't collect or review criminal history information as part of the admission process. However, individuals who are admitted to Carnegie Mellon will be required to disclose any past criminal conviction as part of the enrollment process. Learn how Carnegie Mellon considers criminal history (<https://www.cmu.edu/hub/consumer-information/#criminaljustice>) information.

COLLEGE CRITERIA

Each college/program at Carnegie Mellon has admission criteria specifically related to each course of study.

Admission to the Schools of Drama and Music is based primarily on a pre-screen, audition or (for select School of Music programs) portfolio review. Applicants to the Schools of Architecture, Art and Design will be evaluated

not only on the basis of their portfolio review but also on their academic performance.

Applicants to the College of Engineering, Mellon College of Science, School of Computer Science and Tepper School of Business will be evaluated on their academic performance, with emphasis on strength in mathematics and science. Applicants to the Dietrich College of Humanities and Social Sciences and the Information Systems program will be evaluated on their academic performance, with emphasis on reading and comprehension abilities along with mathematics coursework. We'll also evaluate both groups of applicants based on their ability to communicate thoughts and ideas in writing.

Applicants should be aware of our admission requirements (<https://www.cmu.edu/admission/admission/undergraduate-admission-requirements/>) (secondary school preparation, nonacademic information and counselor and teacher recommendations) when submitting applications.

Think carefully about your Carnegie Mellon college selection(s) before applying. While you may apply to up to two colleges or programs that match your interests, bear in mind that most applicants will only be selected for their highest-choice college to which they're admissible. It's rare for students, even of the highest quality, to be granted admission to more than one of their college selections. Early Decision and transfer candidates may only apply to their first-choice college or program at Carnegie Mellon. Please note that admission to the university is always contingent upon maintaining academic performance and community conduct commensurate with that which resulted in admission. Admission decisions will be rescinded for failure to maintain strong academic performance, community conduct, honesty, maturity and/or moral character. For more information, view The Word student handbook (<https://www.cmu.edu/student-affairs/theword/>).

Applying as a First-Year Student

If you're applying to Carnegie Mellon as a first-year student entering in fall 2024, here's how to apply. Graduate students should refer to the Graduate Education website (<https://www.cmu.edu/graduate/admissions/>) for application instructions.

1. Choose your admission plan. Carnegie Mellon offers the following application plans: Regular Decision, Early Decision 1 and 2 and Early Admission for high school juniors. *Please note: Carnegie Mellon doesn't offer Early Action.*

- Early Decision 1 applications and supporting admission documents are due by November 1.
- Early Decision 2 applications are due by January 3 and supporting admission documents by January 15.
- All other first-year applications besides Regular Decision Drama and Music are due by January 3 and supporting admission documents by January 15. If you're applying to the Schools of Music or Drama this way, your application and materials are due December 1.

2. Complete the online Common Application (<http://www.commonapp.org/>). If you're applying during our Early Decision 2 or Regular Decision plans, please request that your secondary school counselor submit all secondary school transcripts, including senior year courses and a school profile, to the Office of Admission as close to January 3 as possible, but no later than January 15. Mid-year grades should be submitted as soon as possible after they become available. It's your responsibility to check what documents we've received on the Where Am I in the Process? portal to acknowledge receipt of these items. Receipt of mailed or faxed materials will be found on your Where Am I in the Process? portal within 7–10 business days after being received by the Office of Admission.

3. Apply for admission only to the specific college(s) or program(s) in which you're interested.

- Rank your program and/or major preference.
- You may apply to up to two colleges/programs. (Early Decision and transfer candidates may only apply to one college/program.)
- If applying to more than one college, you must detail your multiple interests in the Carnegie Mellon short response questions.
- Be sure to review the admission requirements for each college/program.

4. Follow these guidelines for each specific area of interest:

ALL COLLEGES AND PROGRAMS EXCEPT COLLEGE OF FINE ARTS (CFA)

We strongly urge applicants to indicate a program and/or departmental preference at the time they apply. Although students might not declare a major until the end of their first or second years, we've had to limit access to certain departments.

COLLEGE OF FINE ARTS (CFA)

Students applying to CFA must apply directly to one or more of the following: School of Architecture, School of Art, School of Design, School of Drama or School of Music.

5. Send a non-refundable application fee of \$75 electronically as you complete the Common Application. This fee is required. However, if you have a College Board or NACAC fee waiver or if you have any of the Common Application's listed economic indicators, you can note this on your registration form in order to have your payment waived. Only U.S. citizens, permanent residents and DACA students are eligible for fee waivers. An additional audition/portfolio review fee will be required at the time of online registration for Drama and Music pre-screening, audition or music portfolio review. For School of Music applicants, the additional audition fee is \$55. For School of Drama applicants, the audition or prescreening fee is \$120. These fees are payable at the time of reserving a pre-screening, audition or portfolio review online on the Fine Arts section of our website. For applicants to the Schools of Art, Architecture or Design, there is a \$20 fee to submit the portfolio.

6. If you choose to have your scores considered, you're required to submit all official results of either the SAT or the ACT. While we're interested in the general pattern of your scores, we give most weight to the highest score you've received on the SAT. On the ACT, we give most weight to the set of scores corresponding to the highest composite score. Carnegie Mellon doesn't superscore the ACT. We believe that college admission testing in the 9th and 10th grades adds to the anxiety of a process that students won't encounter for several years. As a result, we encourage students to submit 11th or 12th grade SAT or ACT scores (tests taken the summer after 10th grade are appropriate). While earlier tests may measure knowledge at the time they are taken, that level of knowledge gradually evolves and doesn't fully represent the knowledge students bring to college first-year courses. Should students present tests taken two or more years in advance of their first-year experience, we have to take the timing of the test result into consideration. The greater the amount of time prior to college matriculation, the less we can rely on the test result as a fair representation of their preparation entering first-year college courses.

7. If English isn't one of your first languages, submit additional test results. Applicants who don't speak English as a first language must submit the results of the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS) or the Duolingo English Test.

8. If you're applying to the College of Fine Arts, submit your Common Application before completing portfolio submission, pre-screening or audition requirements. All of our fine arts programs require that students apply to the university and obtain their Application ID before registering for a pre-screening or audition, or before submitting a portfolio. Early Decision 1 is not available for acting, directing, dramaturgy, music theater or the School of Music. Early Decision 2 is not available for the Schools of Art, Design, Drama or Music. If you're applying Regular Decision to the Schools of Drama or Music, apply by December 1. You must also submit your supporting materials by December 1. Submissions after December 1 may not be considered. Refer to the table on page 3 for admission deadlines. Please note that Carnegie Mellon reserves the right to verify original work in admission essays using *Turnitin.com*.

9. Sign the "FERPA Release Authorization" on the Common Application School Report Form and then request your secondary school counselor complete the form. Your counselor should submit this form to the Office of Admission along with the school profile and your transcript.

10. Choose a teacher to complete the Common Application Teacher Recommendation Form. Make sure it's submitted to the Office of Admission by:

- Early Decision 1: November 1
- Early Decision 2: January 15
- Regular Decision: January 15

11. If you're applying for financial aid, submit all requested documents. We require financial aid applicants to complete the Free Application for Federal Student Aid (FAFSA) (<http://www.fafsa.gov>). Carnegie Mellon's federal code is 003242. You must also complete the CSS Profile (<https://profileonline.collegeboard.com>) and submit signed copies of parent/guardian and student tax documents.

Application Notification

- Students applying under the Early Decision 1 Plan will be notified of our decisions by December 15.
- Students applying under the Early Decision 2 Plan will be notified of our decisions by February 1.
- Students applying under the Regular Decision Plan will be notified of our decisions by April 1.
- Students who are applying for financial aid will also receive financial aid decisions by April 1 provided they submitted their financial aid forms by the February 15 financial aid deadline.

If you're offered admission and wish to enroll at Carnegie Mellon, you're required to pay an \$800 non-refundable enrollment deposit by May 1 in order to reserve your place in the first-year class and in university housing. This deposit will be credited to your first semester's charges. The admission staff assumes that a student's deposit to Carnegie Mellon is their only deposit. We reserve the right to cancel our offer of admission if a student also posts a tuition deposit at another university. During the summer, information concerning registration, enrollment, insurance, orientation, housing and dining services and more will be communicated to all incoming students.

Deferred Admission

If you're admitted to Carnegie Mellon and wish to defer your admission for one year, you must submit a written request to the Office of Admission. If permission is granted, your enrollment deposit must be paid in order to confirm enrollment for the following year. You must agree not to apply to or enroll in a full- or part-time degree program at another institution in the interim.

APPLICATION MISREPRESENTATION

We value academic and artistic integrity and authenticity in the admission process. Furthermore, Carnegie Mellon assumes that lists of activities, accomplishments, awards, essays and recommendations are authentic, original and accurately reflect student achievements. We reserve the right to launch an investigation when falsified transcripts, artistic submissions of work or misrepresentation of credentials that are not accurate, original and authentic representations of a student's ability and level of accomplishment are suspected. A student's admission status will be placed on hold during an investigation and can result in the cancellation of an application or the withdrawal of an offer of admission. Carnegie Mellon does report confirmed cases of misrepresentation to the Common Application.

All offers of admission are based on the assumption that students will maintain the level of academic performance and community conduct that has resulted in admission to Carnegie Mellon. Admitted and enrolled students are expected to abide by Carnegie Mellon's code of conduct, found within our student handbook, *The Word*.

Application Plans**Early Decision**

These plans are ideal for students who view Carnegie Mellon as their first choice or if it has become their first choice before Regular Decision applications are due. For Early Decision 1, you'll apply by **November 1**; for Early Decision 2, **January 3**. You'll apply to only one college within the university and receive your admission decision earlier in your senior year than our Regular Decision plan (by December 15 for Early Decision 1 and February 1 for Early Decision 2). If you're admitted under Early Decision, you've agreed to enroll, so this isn't the best plan if you want to compare financial aid offers from other institutions. Early Decision also isn't available if you're under the age of 17 or if you're applying Early Admission as a high school junior. Early Decision 1 is not available for acting, directing, dramaturgy, music theater or the School of Music. Early Decision 2 is not available for the College of Fine Arts.

We give three admission decisions for students applying Early Decision: admit, not admit or, in rare cases, defer to Regular Decision. Students who receive a "not admit" decision during Early Decision aren't eligible to apply for Regular Decision.

If you apply Early Decision, we encourage you to submit applications to other colleges/universities. However, you must agree to withdraw these applications if notified of Early Decision acceptance.

Applying Early Decision won't affect your overall admission decision. Students applying Early and Regular Decision are admitted at almost exactly the same rate.

Regular Decision

Regular Decision is our most popular application option. You'll apply to up to two colleges by **January 3** (December 1 for Drama and Music applicants). You'll be notified of your decision no later than April 1. Admitted students will have until May 1 to accept our offer of admission.

Early Admission

This is a rare opportunity for highly qualified high school juniors to apply early to Carnegie Mellon. Early Admission is ideal for mature, responsible juniors who have exhausted their high schools' most rigorous courses. Like Regular Decision, Early Admission applicants must apply by **January 3**.

While the campus environment is rich in educational and social opportunities, students younger than traditional college age often face unique challenges in becoming acclimated to the university community.

It's the responsibility of students under the age of 17 and their parents to contact the Dean of Student Affairs Office to discuss services and resources available in addressing their specific needs. Only students 17 years of age or older are permitted to reside in university housing. The university doesn't participate in any homestay programs.

Applying as a Transfer Student

Each year, Carnegie Mellon admits a very small number of transfer students where space permits. The policy for transferring into Carnegie Mellon varies from college to college. If you're interested in transferring into one of our academic programs, we must first make sure there's space available in your program of interest. Please note that space in these programs is extremely limited. If there's space, we'll look closely at your official college transcript, professor recommendations, high school grades and test scores (all SAT, ACT or language proficiency examination scores, if available). If you don't have official ACT or SAT results, there's no expectation to submit them.

In the College of Fine Arts, most transfer applicants are required to complete a pre-screen, audition or portfolio review.

Transfer Application Instructions

1. Apply for admission to the specific college or program in which you're interested. Make sure to note which department you prefer on the Common Application. Transfer students will only be considered for one college.

- Fall transfer is possible if space is available.
- Spring transfer may be possible for some colleges, but is extremely limited due to space constraints. CFA applicants can't apply for spring admission.
- External transfers are unable to apply to BXA programs.
- External transfers are unable to apply to BXA programs

Please submit your application by the deadline:

- Spring transfer: October 15
- Fall transfer: February 15 (December 1 for performing arts, January 3 for visual arts)

2. Send a non-refundable application fee of \$75 electronically as you complete the Common Application. This application fee is required, except in extenuating financial circumstances. To request a waiver, send us a letter from a college advisor or your dean requesting an application fee waiver in place of the application fee. Only U.S. citizens or permanent residents are eligible for fee waivers.

3. Send all college/university and secondary/high school transcripts to the Office of Admission. If you wish to attend Carnegie Mellon as a transfer student and have previously applied to the university, you must resubmit an updated Common Application with your application fee and all other required materials. *If you're admitted, make arrangements to have a final copy of your college transcript(s) sent to Carnegie Mellon.*

4. Send a copy of course descriptions from a college catalog from each college/university you attended so we can evaluate transferable credits. Course descriptions should be sent through the Common Application or completing a form electronically (<https://admission.cmu.edu/register/collegecourses/>). You should copy and paste your course descriptions into a single document, saved as a PDF that has your name, address and Common Application ID on the first page. *If you're applying to Dietrich College of Humanities and Social Sciences for admission to select programs, you may be also asked to submit course syllabi.*

5. Sign the "FERPA Release Authorization" on the Common Application College Report Form. Have your dean or advisor at the

college you're attending (or last attended) complete this form. Your dean or advisor should return the form directly to the Office of Admission.

6. Once available, check your Where Am I in the Process? portal for an official admission decision. If accepted, you'll need to complete an enrollment reply form. Please note that admission to the university is contingent upon maintaining academic performance and community conduct commensurate with that which resulted in admission. Admission decisions will be rescinded for failure to maintain strong academic performance, community conduct, honesty, maturity and moral character

| If planning on: | Submit all financial aid documents by: | To be notified by: |
|------------------------------------|--|------------------------------------|
| Spring transfer | November 1 | December 15 (or soon after) |
| Fall transfer (CFA) | February 15 | April 15 |
| Fall transfer (all other colleges) | March 1 | No later than May 31 |

Deposit Information for Transfers

If you're offered admission for the spring semester, Carnegie Mellon does not require a tuition deposit due to the short time interval between December 15 and the start of the spring semester. If you're offered admission to the College of Fine Arts for the fall semester, you must pay a non-refundable deposit of \$800 by May 1. If you are offered admission to Engineering, DC, IS, MCS, SCS, or Tepper for the fall semester, you must pay a non-refundable \$800 deposit by June 1, even if you are receiving financial aid. The enrollment deposit will reserve your place at the university and a place in university housing if available. It will be credited to the first semester charges.

IMPORTANT: If you accept our offer of admission, we assume that your tuition deposit to Carnegie Mellon is your only tuition deposit. We reserve the right to cancel our offer of admission if you post a tuition deposit at more than one university. Enrollment deposits received after the deposit deadline will be returned if space is no longer available.

University Housing for Transfers

University housing isn't guaranteed for transfer students. Housing Services has a webpage available to help you locate housing accommodations (<https://offcampus.housing.cmu.edu/>) in the local area in the event that campus housing isn't available.

Transfer Credit Evaluated on Individual Basis

The college/school to which you're admitted will determine transfer credit for courses you've taken at other universities. We only offer transfer credit evaluations to admitted students. Transfer credit is considered on an individual basis. We may award elective credit for courses with no Carnegie Mellon equivalent.

Transfer credit for courses you're taking while we're reviewing your existing college record depends upon successful completion of each course. Grades aren't transferred — only credits. Sometimes transfer students have to take specific courses and accumulate a larger total number of credits than the normal amount required for graduation. The time it takes for you to graduate will depend on the time you need to complete the full university degree requirements — not on your class standing at a previous institution.

If you transfer in the fall semester, you'll be given instructions on how to receive an estimate of the additional academic work you must complete in order to fulfill the university degree requirements.

If you transfer in the spring semester, you'll have the opportunity to meet with an associate dean or advisor in order to outline the additional academic work you must complete to meet the university degree requirements.

It's best for transfer students in CFA to assume they'll receive first-year status. Occasionally advanced standing is awarded based on review of previous college courses.

You must make arrangements to have a final copy of your college transcript(s) forwarded to Carnegie Mellon's Office of Admission by July 1.

Applying as an International Student

International students should apply to Carnegie Mellon using the same procedures outlined for either first-year or transfer students. Also note this additional information:

- Carnegie Mellon doesn't offer financial aid or installment plans to international students. International students aren't eligible for application fee waivers.

- If English isn't one of your first languages, you're required to take the Test of English as a Foreign Language (TOEFL), the International English Language Testing System (IELTS), the Duolingo English Test, or the Cambridge English Assessment.
 - TOEFL: We accept three versions of the TOEFL - the iBT, the iBT Home Edition and the Essentials exam. Carnegie Mellon requires scores of at least 102 on the TOEFL iBT or iBT Home Edition or at least 11 on the TOEFL Essentials. Sub-scores are also carefully reviewed, with consideration given to those with sub-scores of 25 or higher on the TOEFL iBT or iBT Home Edition or 11 or higher on the TOEFL Essentials. Carnegie Mellon doesn't consider TOEFL MyBest results.
 - IELTS: Carnegie Mellon requires an overall score of at least 7.5 on the IELTS. Sub-scores are also carefully reviewed, with consideration given to those with sub-scores of 7.5 in each section.
 - Duolingo English Test: Beginning Fall 2021, Carnegie Mellon will accept Duolingo's English Test. We require at least a 135 overall and give consideration to those with the following subscores and above: Literacy, 135; Conversation, 130; Comprehension, 145; Production, 113.

Scores should be no more than two years old at the time of application, and we prefer that you submit all English proficiency test results from the past two years. For information about score considerations, please check our website (<https://www.cmu.edu/admission/>) for updates.

Regular Decision applicants should arrange to have these scores sent to Carnegie Mellon no later than January 7.

- InitialView interviews (<https://initialview.com/home/>) are recommended for non-native English speakers but aren't required. Often these interviews can measure readiness for engagement in the classroom and also showcase a student's personality, likes and dislikes, as well as the area of intended major. InitialView interviews can show English language proficiency while also corroborating the application with more details about the student.

Advanced Placement Consideration

Advanced Placement Program

Carnegie Mellon recognizes the Advanced Placement program and may grant advanced placement and credit for test scores of four or five (<https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html>). When you take the tests, be sure you request that the results be sent to Carnegie Mellon.

INTERNATIONAL BACCALAUREATE PROGRAM

Carnegie Mellon also recognizes the International Baccalaureate Examination and may grant advanced standing and/or credit in various fields if scores on the higher level examination range from six and seven. (<https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html>) Make sure you send these examination results to Carnegie Mellon.

College-Level Work

We may grant placement or credit for college work you've completed while in high school. Please have your college transcript(s) sent to Carnegie Mellon for transfer credit evaluation. Please send the descriptions of the college courses as well.

Cambridge General Certificate of Education

Carnegie Mellon recognizes the Cambridge GCE A-Level (advanced level) examinations in various higher-level subjects and may grant advanced placement and/or credit for exemplary grades (<https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html>). Please note that we don't accept GCE "O" level examinations for placement.

Special Administration Results during COVID-19

If your AP or IB tests were impacted by COVID-19, you may still be able to receive credit. Carnegie Mellon will accept official test results from AP special testing administrations offered during COVID-19 and taken at home. We'll also accept calculated official IB results if your IB tests were canceled because of COVID-19. For more information, visit the university registrar's site (<http://cmu.edu/hub/registrar/registration/ap-transfer-credit.html>).

College of Fine Arts Requirements

Detailed information may be found on the Office of Admission website (<https://www.cmu.edu/admission/>).

Deadlines

- Early Decision 1 applicants must submit a complete admission application, including any required artistic evaluation, by November 1.
- Early Decision 2 applicants must submit an application and any required artistic evaluation by January 3. Supporting admission documents (not including any required artistic components) are due January 15. The School of Architecture is the only College of Fine Arts school to participate in Early Decision 2.
- Regular Decision applicants to Drama and Music must apply and make all pre-screen, audition or music portfolio review reservations by December 1.
- Regular Decision applicants to Art, Architecture and Design must apply by January 3 and submit their portfolio no later than January 15.
- We recommend that you apply for admission as early as possible in order to register for a pre-screen, audition or portfolio review, which fill on a first-come, first-served basis.

Communicating Admission Decisions

- Final admission decisions aren't made at the time of your audition or portfolio review. We'll consider the artistic evaluation alongside the rest of your application and notify you of your admission decision no later than April 1 (December 15 for Early Decision 1 applicants, February 1 for Early Decision 2 applicants).

BXA Intercollege Degree Programs

The BXA programs (p. 893) are intercollege degree-granting programs designed for students who'd like to combine and blend their interests in the fine arts and either computer science (BCSA), humanities/social sciences (BHA), natural sciences/mathematics (BSA) or engineering studies (BESA). To apply for a BXA program, select the College of Fine Arts school you wish to apply to. We'll then ask if you'd like to be considered for a BXA program.

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA)

To be considered for the BCSA program, you must apply and be admitted to both CFA and SCS (you must select a CFA school and SCS major on the Common Application).

BACHELOR OF HUMANITIES AND ARTS (BHA)

To be considered for the BHA program, a student must apply and be admitted to both CFA and DC (you must select a CFA school and DC major on the Common Application).

BACHELOR OF SCIENCE AND ARTS (BSA)

To be considered for the BSA program, a student must apply and be admitted to both CFA and MCS (you must select a CFA school and MCS major on the Common Application).

BACHELOR OF ENGINEERING STUDIES AND ARTS (BESA)

To be considered for the BESA program, a student must apply and be admitted to both CFA and CIT (you must select a CFA school and CIT major on the Common Application).

In your accompanying application essay, please describe your interdisciplinary goals in both areas and how the BXA program would provide the opportunity and framework for you to accomplish these objectives. This essay is a central component in the selection process. You do not need to complete another essay. If you are selected for this program, you will be notified in your admission decision letter.

BXA options aren't available for those applying to the School of Drama for Music Theater, Acting or Directing, or for external transfer applicants. Under Early Decision 1, BXA is only available for the School of Drama options in Design/Production and the Schools of Architecture, Art and Design.

Exploring Carnegie Mellon

College visits are some of the best ways to discover which school is right for you. We offer both in-person and online visit opportunities. Here are just

a few ways to experience Carnegie Mellon from home, on campus and in your area. Register for all visit opportunities here (<https://www.cmu.edu/admission/visit/>).

CARNEGIE MELLON ON CAMPUS

Information Sessions

The Office of Admission may offer on-campus information sessions (https://admission.cmu.edu/portal/on_campus_information_session/) throughout the year. The session offers an experiential look at the university through student and faculty stories. You'll have the opportunity to learn more about Carnegie Mellon's areas of study, admission, financial aid and the city of Pittsburgh.

Campus Tour

During our campus tour, our Tartan Ambassadors will show you classrooms, laboratories, traditions and unique architecture around campus. They'll also be answering your questions and sharing an insiders perspective on the Carnegie Mellon experience.

Outdoor Campus Walking Route

On this self-guided touring experience, you'll have the opportunity to walk an outdoor path around campus for one hour. A physical version of the Walking Route map is available in the vestibule of Warner Hall or at the Coulter Welcome Center.

Admission Counseling Session

An Admission Counseling Session allows you to meet one-on-one with an Admission Counselor to ask any questions you have regarding Carnegie Mellon, the opportunities on campus, or the application and admission process. These sessions are typically 20-30 minutes long.

Contact Carnegie Mellon for Assistance

If you need assistance while visiting campus, please contact us at admission@andrew.cmu.edu or 412.268.2082. We'll help meet your needs during your visit!

Carnegie Mellon Online

Virtual Campus Tours

When you can't make it to campus, we've got you covered. Our Tartan Ambassadors are hosting live Virtual Tours (https://admission.cmu.edu/portal/virtual_tours/) so you can experience Carnegie Mellon's campus from anywhere in the world. These Virtual Tours will offer you the opportunity to explore our campus while hearing more about the Carnegie Mellon experience.

Remote Information Sessions

Our remote Information Sessions (https://admission.cmu.edu/portal/remote_info_sessions/) are live events designed for you to learn more about the Carnegie Mellon experience. Led by our admission counselors, these hour-long webinars feature student stories, faculty highlights and detailed information about academics, student life and the admission and financial aid processes. You'll also have an opportunity to ask questions.

Carnegie Mellon Snapshot

If you're looking for an abbreviated information session that's still rich in content, check out our Carnegie Mellon Snapshot webinar (https://admission.cmu.edu/portal/remote_info_sessions/). The Snapshot includes a 20-minute university overview and 10-minute counselor Q&A. The information session provides essential information on our colleges and programs and our admission and financial aid processes, while the Q&A is your opportunity to ask an admission counselor any of your questions.

Remote Admission Counseling Session

We're currently offering remote admission counseling sessions (https://admission.cmu.edu/portal/adm_counseling_session_videocon/) for rising high school juniors and seniors. These virtual sessions allow students approaching the time of application to ask an admission counselor questions and seek guidance about Carnegie Mellon's unique colleges/programs and the admission process. Students and their families can join these sessions via video or phone call. Admission counseling sessions last about 20-30 minutes and allow time for parents or families to ask questions.

Tartan Talks

Tartan Talks (https://admission.cmu.edu/portal/Tartan_Talk/) are an online student panel series where interested visitors can learn more about the student experience at Carnegie Mellon University. Each Tartan Talk will

feature our Tartan Ambassadors talking about their student involvement within academics, activities, research, the city of Pittsburgh and more. Bring your questions, and our Tartan Ambassadors will be ready to answer!

Carnegie Mellon in Your Area

Information Sessions Near You

We realize that it's not always possible for you to come to campus. The Admission staff does travel to different parts of the country and may offer information sessions in a city near you (<https://www.cmu.edu/admission/visit/visit-opportunities-in-your-area/>).

2023-2024 Cost of Attendance

The cost of attendance listed below references typical resident, commuter and off-campus undergraduate students. The academic year tuition charges are for full-time undergraduate students. A full-time student is one registered in a degree program and carrying a schedule of at least 36 units per semester. A student enrolled for less than 36 units per semester will be charged tuition on a per-unit basis. The university reserves the right to change its charges without notice. For full cost of attendance information, visit www.cmu.edu/sfs/tuition (<https://www.cmu.edu/sfs/tuition/>).

First-Years Entering Fall 2023

Per-unit tuition rate: \$865

| | Resident | Commuter |
|--|-----------------|-----------------|
| Tuition | 62,260 | 62,260 |
| Activity Fee | 288 | 288 |
| Transportation Fee | 256 | 256 |
| Media Fee | 10 | 10 |
| Technology Fee | 460 | 460 |
| Living Expenses - Housing (1) | 10,400 | 0 |
| Living Expenses - Food (2) | 7,068 | 3,534 |
| Books, Course Materials, Supplies, Equipment (3) | 1,000 | 1,000 |
| Estimated Loan Fees & Miscellaneous (3) | 1,400 | 1,400 |
| Transportation Allowance (3, 4) | 0 | 680 |
| Totals | \$83,142 | \$69,888 |

Undergraduate Students Who Entered Fall 2022 & Earlier

Per-unit tuition rate: \$865

| | Resident | Commuter | Off-Campus |
|--|-----------------|-----------------|-----------------|
| Tuition | 62,260 | 62,260 | 62,260 |
| Activity Fee | 288 | 288 | 288 |
| Transportation Fee | 256 | 256 | 256 |
| Media Fee | 10 | 10 | 10 |
| Technology Fee | 460 | 460 | 460 |
| Living Expenses - Housing (1) | 10,400 | 0 | 10,400 |
| Living Expenses - Food (2) | 7,068 | 3,534 | 7,068 |
| Books, Course Materials, Supplies, Equipment (3) | 1,000 | 1,000 | 1,000 |
| Estimated Loan Fees & Miscellaneous (3) | 1,400 | 1,400 | 1,400 |
| Transportation Allowance (3, 4) | 0 | 680 | 0 |
| Totals | \$83,142 | \$69,888 | \$83,142 |

Footnotes:

¹ All incoming first-year students are required to live on campus. Permission for first-year students to commute must be granted by Student Affairs. Off-campus housing expense is estimated at \$8,900.

² Food expenses for commuters is estimated at 50% of first-year resident food expenses. For returning students, resident and off-campus food expenses is estimated using first-year resident food expenses minus \$310.

³ These expenses do not appear on the student account.

⁴ Transportation allowance for resident and off-campus students varies based on home state.

Orientation

An Orientation Fee in the amount of \$555 is also charged to incoming first-year students for the fall semester only.

Health Insurance

In addition, health insurance coverage is required at an estimated cost of \$2,577/year. If a student is covered under a family's health plan, a waiver may be submitted to University Health Services for approval. View more details at www.cmu.edu/health-services/student-insurance (<http://www.cmu.edu/health-services/student-insurance/>).

Office of Enrollment Management

Dr. Kristina Wong Davis, Vice Provost for Enrollment Management & Dean of Admission
www.cmu.edu/hub (<http://www.cmu.edu/hub/>)

The Office of the Vice Provost for Enrollment Management and Dean of Admission provides vision and leadership for all aspects of Carnegie Mellon's enrollment process. From the point of recruitment, the office is committed to fostering an environment where students and families feel welcome, prepared and supported during their transition to life at CMU all the way through Commencement. The office supports student success and positive outcomes by fostering collaborative partnerships across the university, promoting data driven decision-making, and planning for long-term enrollment strategy.

Enrollment Management is comprised of five functional areas and a one-stop student service center, which provide student-focused and highly efficient services and programs to support and enhance CMU's recruitment and retention goals. The Office of Admission (p. 8), The HUB (p. 14), University Registrar's Office (p. 15), Student Financial Services (p. 14), Office of International Education (p. 16), and Enrollment Systems work together to serve students, families and the campus community through strategic enrollment planning and delivering valuable and effective student support and administrative services.

The HUB & ID Card Services

Melissa Skasik, *Interim Co-Director of The HUB*
 Carey Zehnder, *Interim Co-Director of The HUB*
Location: Warner Hall A12, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-8084
thehub@andrew.cmu.edu
www.cmu.edu/hub (<https://www.cmu.edu/hub/>)

The HUB Student Service Center

The HUB staff delivers comprehensive service and counsel to students and families regarding financial aid, billing and payment, registration, academic records, and ID Card services. In direct support of student enrollment and persistence, The HUB offers students and families highly integrated information through personal attention and technologically responsive tools in a professional, forward-thinking, and accessible environment.

Professional staff in The HUB serve as liaisons for specific colleges and support enrolled students with key aspects of the enrollment process – financial aid, billing and registration. Contact information for assigned HUB liaisons can be found on The HUB website (<https://www.cmu.edu/hub/contact/>) or the student's personalized Student Information Online (SIO) account.

Regular office hours for The HUB are: Monday and Wednesday (9 a.m. to 4:30 p.m.), Tuesday and Thursday (10:30 a.m. to 4:30 p.m.), and Friday (9 a.m. to 3 p.m.). These hours are subject to change, so visitors are asked to check The HUB's website (<https://www.cmu.edu/hub/contact/>) for the most up-to-date hours.

ID Card Services in The HUB

One of the most important items students will need at Carnegie Mellon is their official identification card. The CMU ID Card, administered through The HUB, classifies you as a member of the Carnegie Mellon community and is a part of everyday campus life. From bus access and Plaid Cash to campus events and museum entry, the ID Card is an essential tool for on and off campus.

View more information at www.cmu.edu/idplus (<http://www.cmu.edu/idplus/>).

Student Financial Services

Brian Hill, *Assistant Vice President & Director of Student Finances and Systems*
Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
thehub@andrew.cmu.edu

www.cmu.edu/sfs (<https://www.cmu.edu/sfs/>)

Student Financial Aid Office

Matthew Metz, *Director of Student Financial Aid*
Location: Warner Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-8186
Fax: 412-268-6651
www.cmu.edu/sfs/financial-aid (<https://www.cmu.edu/sfs/financial-aid/>)

In alignment with the university's enrollment goals, Student Financial Aid consistently optimizes the utilization of all financial aid resources in order to recruit and retain a high quality and diverse student population. Student Financial Aid strives to deliver superior services that exceed the expectations of students, parents, and internal and external constituencies. Student Financial Aid identifies, creates and delivers strategies that facilitate the integration of financial aid policies. These policies align with current and future university recruitment, retention and enrollment priorities.

How Aid Works

Our financial aid program is need-based, meaning that all aid eligibility is determined by a student's family's financial circumstances. While student's and families have the primary responsibility for paying for college, financial aid can bridge the gap between the total costs and ability to pay.

Nearly half of our undergraduate students rely on some type of financial aid to pay for educational expenses. While many of our graduate students are offered departmental scholarships, grants, stipends, assistantships and fellowships, some rely on other resources, like federal loans, available through the Student Financial Aid Office.

Student financial aid packages may be comprised of scholarships and grants, student employment, and loans. In addition, options like the monthly payment plan may be suggested as a way to help budget payments of educational expenses and to limit debt. Like any major investment, most families pay for education with a mix of current income, savings and borrowing. Finding the right balance among these resources can save money.

For more information or complete steps for applying for financial aid at CMU, visit www.cmu.edu/sfs/financial-aid (<https://www.cmu.edu/sfs/financial-aid/>).

Types of Financial Aid

There are several types of financial aid available to students, such as federal and private loans, university scholarships, outside scholarships, federal and state grants, and student employment. A full listing and explanation of these types of aid may be found at www.cmu.edu/sfs/financial-aid/types (<https://www.cmu.edu/sfs/financial-aid/types/>).

Student Financial Aid Terms and Conditions

All students, regardless of whether they are financial aid recipients, are required to confirm agreement to the university's student financial aid terms and conditions upon their initial log-in to Student Information Online (SIO) and before any financial aid disburses to their account. The terms and conditions apply to all student financial aid, regardless of source (e.g., federal, state or institutional), including grants, scholarships, fellowships, loans and work-study awards.

Learn more at www.cmu.edu/sfs/financial-aid/terms.html (<https://www.cmu.edu/sfs/financial-aid/terms.html>).

INTERNATIONAL Undergraduate Students

Only U.S. Citizens or Eligible Non-citizens are eligible to receive federal student aid. U.S. Citizens who were not born in the United States will need to send documentation of citizenship (i.e., a copy of passport or naturalization certificate). Verification is required for Eligible Non-citizens or refugees. Acceptable forms of verification include a photocopy of both sides of the student's I-551 or I-551C card.

Undergraduate international students are not eligible to receive federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Student Accounts Office

Kurt Steinmiller, *Director of Student Accounts*

Location: Warner Hall, 5000 Forbes Avenue, Pittsburgh, PA 15213

Phone: 412-268-8186

Fax: 412-268-6651

www.cmu.edu/sfs/billing (<https://www.cmu.edu/sfs/billing/>)

The Student Accounts Office serves the university's various academic and administrative departments by processing and invoicing all student-related financial activity and managing the corresponding student financial obligations resulting from this activity. The office strives to serve students by accurately reflecting and communicating these financial obligations, providing timely and consistent responses to inquiries, and instilling financial responsibility and accountability with clear and concise guidance.

Student Financial Obligation Terms

Carnegie Mellon University wishes to be transparent about the financial expectations of students to the university. All students must acknowledge their agreement to the financial obligation terms only one time during their career at the university before access to Student Information Online (SIO) can be granted.

The student financial obligation terms (<https://www.cmu.edu/sfs/docs/sfo-terms.pdf>) (pdf) detail the student's responsibility to remit payment for charges incurred at the university as well as repercussions of non-payment.

UNIVERSITY CHARGES

All charges incurred at the university are reflected on your student account. Charges include tuition and fees and may include housing, dining, sorority or fraternity charges, health insurance, Plaid Cash, and other miscellaneous charges incurred. Miscellaneous charges may include, but are not limited to, music lessons, library fines, parking fines, or emergency loans.

STUDENT ACCOUNT INVOICES

Student account invoices are produced on the last day of each month. Invoices detail all transactions processed in the month, as well as any charges due in the future. Students receive an email notification to their Andrew email account when an invoice is ready for viewing on Student Information Online (SIO) (<https://www.cmu.edu/hub/sio/about.html>). Payments for amounts due from a monthly invoice must be received by the 15th of the next calendar month. Any amounts not paid by the stated due date are subject to a 1.5% interest charge each month until the balance is paid in full.

Carnegie Mellon does not print and mail student account invoices.

BILLING AUTHORIZATIONS & MY PLAID STUDENT

Students may authorize Carnegie Mellon to send a PDF copy of their invoice to another individual's (parent, spouse, etc.) email address. After completing the authorization process, designated recipients will receive an email with a PDF attachment of the invoice and any related billing messages.

Students can also invite a bill payer or other individual to use My Plaid Student (MPS) (<https://www.cmu.edu/hub/MyPlaidStudent/>), which gives authorized users access to a student's invoices and student account activity, as well as the ability to make payments to the student's account. Students may also authorize their users to request enrollment verifications, and view grades and course schedules, via MPS. .

View more information at www.cmu.edu/hub/parents-and-family (<https://www.cmu.edu/hub/parents-and-family/>).

Tuition Assessment

The tuition charged to each student will be automatically adjusted on the 10th regularly scheduled class day (refer to the specific date noted in the Official Academic Calendar (<https://www.cmu.edu/hub/calendar/>) as the "last day to add courses") based upon each student's schedule at that time. The tuition charged will be increased whenever the number of units added justifies tuition charges greater than those paid by the student at the time of fee settlement. After that time, no tuition adjustments will be made, with the exception of second minis for that particular semester.

For additional information, view www.cmu.edu/sfs/tuition/adjustment (<https://www.cmu.edu/sfs/tuition/adjustment/>).

Payment Options

Carnegie Mellon University is pleased to offer a wide variety of payment options for students and families. A full listing of these, as well as more

information on each type, is available at www.cmu.edu/sfs/billing/payments (<https://www.cmu.edu/sfs/billing/payments/>).

We recommend that students enroll in Online Banking by linking a U.S. bank account to their student account via SIO. This is the fastest, easiest, and most convenient way to make a payment to or receive a refund from the university. The university does not initiate a withdrawal from a student's bank account; funds are only withdrawn when a student schedules a payment through SIO.

Refunds

If a student account has a negative balance resulting from an overpayment, financial aid, or a reduction of charges, the Student Accounts Office will review the account and issue a refund.

All students are encouraged to authorize electronic deposit of their student account refunds directly into their U.S. checking or savings accounts. Taking advantage of this opportunity eliminates the need to stand in line at The HUB to pick up a refund check and makes the funds available to the student within two business days.

If electronic refunding is not selected, the refund will be generated as a paper check that must be picked up in The HUB. Students who are issued a paper check for a student account refund have six months to cash the check. If the check is not cashed within six months, it will be voided and credited back to the student account and applied to any outstanding charges.

View more details about refunds at www.cmu.edu/sfs/billing/refunds (<https://www.cmu.edu/sfs/billing/refunds.html>).

University Registrar's Office

John Papinchak, *University Registrar*

Location: Warner Hall A19, 5000 Forbes Avenue, Pittsburgh, PA 15213

Fax: 412-268-6651

cmuregistrar@andrew.cmu.edu (university-registrars-office@andrew.cmu.edu)

www.cmu.edu/hub/registrar (<https://www.cmu.edu/hub/registrar/>)

The University Registrar's Office performs the essential roles of administering the collection and maintenance of student records, ensuring their accuracy and integrity, and enforcing academic policies while providing the best possible services. The University Registrar's Office aspires to provide exceptional, environmentally-conscious services, while anticipating and meeting growing customer requirements with innovative processes, training and self-service applications. The office strives to foster and promote an environment of professional development and appreciation.

The University Registrar's Office produces the Academic Calendar (<https://www.cmu.edu/hub/calendar/>).

Enrollment

Enrollment is the process whereby eligible students notify Enrollment Services that they will be attending the university by registering for courses and settling their student accounts. Enrollment must be completed before students may begin classes and before they may utilize university facilities.

Registration

Registration is the process of selecting courses for the upcoming semester and discussing those selections with an academic advisor. We strongly encourage students to meet with their academic advisor before finalizing selections and registering for courses. The University Registrar's Office manages the registration process and related activities for all CMU students. Our goal is that our online services make these processes easy and secure. The registration process may be completed in Student Information Online (SIO) (<https://www.cmu.edu/hub/sio/about.html>) in four easy steps. Students can use the 4 Easy Steps to Registration (<https://www.cmu.edu/hub/registrar/registration/steps/>) webpage to find step-by-step instructions for course registration at CMU, including a pre-registration checklist, how to plan and check course schedules, share with schedules with advisors, confirm registration start time, and register for courses.

For most entering first-year students, registration is accomplished during the summer, with the assistance of associate deans and department heads. Academic placement and elective choice information is collected through mailed questionnaires during June and July. Most first-years complete their schedules and enrollment information prior to the first day of classes.

Currently enrolled students select their courses for the upcoming semester during Registration Week, prior to the end of each semester. The Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) is available online prior to Registration Week, listing available courses along with

general enrollment information. The university reserves the right to make changes to hours, units or instructional staff when such changes seem necessary or advisable.

Students are not permitted to register for courses in which the prerequisites have not been satisfied. Exceptions to the rule may be granted only upon the recommendation of the teaching department concerned. Unless the prerequisites are satisfied or special approval is obtained when the student enters the course, no credit can be allowed for the course. Students are also discouraged from planning schedules in which course time conflicts exist. For exceptional circumstances, however, students may register for, or add, courses with time conflicts. Information about managing course time conflicts is available on the 4 Easy Steps to Registration (<https://www.cmu.edu/hub/registrar/registration/steps/#plan>) webpage.

SUMMER & Non-degree COURSEWORK

Summer semester offers a great opportunity to enroll in Carnegie Mellon's innovative courses and programs in fine arts, business, engineering, technology, liberal arts, and more. Summer classes allow more flexibility to focus on studies outside the typical fast-paced campus environment and more interactive learning with smaller class sizes. Our visiting and non-degree program (<https://www.cmu.edu/hub/registrar/registration/vnd/>) also allows professionals and non-CMU students to expand their education, and to learn from award-winning faculty. Summer courses are offered via three sessions: Summer All, Summer One and Summer Two.

PCHE Cross-Registration

Cross-registration provides opportunities for enriched educational programs by permitting full-time paying undergraduate and graduate students to cross register for one course at a Pittsburgh Council on Higher Education (PCHE) Institution. Students who are paying full-time Carnegie Mellon tuition (per the requirements of their home college) are eligible. The PCHE course may not count towards full-time status. There is no additional tuition charge, except for special course or laboratory fees. Carnegie Mellon students do not acquire status at the Host Institution, but are given library and bookstore privileges. Credit and grades are transferred directly to the home institution. Cross-registration is not applicable during the Summer Session or during intersessions.

For more information, visit www.cmu.edu/hub/registrar/registration/cross (<https://www.cmu.edu/hub/registrar/registration/cross/>).

Faculty Course Evaluations (FCEs)

Students play an integral role in the academic life of the university when they participate in the evaluation of the faculty through the Faculty Course Evaluation process. FCE data is important in the evaluation of teaching and learning, as an important piece of the promotion and tenure process and as part of the process of course design and improvement. Student participation in the FCE process is critical to the university's commitment to quality teaching and academic excellence. Students are strongly encouraged to participate in the process with constructive feedback that is relevant to teaching and course content. More information on the Faculty Course Assessment process and results from previous years may be found at www.cmu.edu/hub/fce (<https://www.cmu.edu/hub/fce/>).

Office of International Education & Study Abroad

Linda Gentile, *Director of OIE*

Location: Cyert Hall, Suite 101, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-5231

o (thehub@andrew.cmu.edu)ie@andrew.cmu.edu (oie@andrew.cmu.edu)

w (<https://www.cmu.edu/hub/>)www.cmu.edu/oie/ (<https://www.cmu.edu/oie/>)

The Office of International Education (OIE) is committed to empowering and inspiring Carnegie Mellon University students, faculty, staff and visitors to achieve their personal and educational goals in a community that encourages and values diverse ideas, life experiences and international perspectives. Supporting the university's educational mission, OIE promotes, advocates and facilitates international and cross-cultural experiences, perspectives and initiatives. OIE is the primary contact for study abroad programs and non-immigrant matters for all students and scholars (foreign professors and researchers) who are not United States citizens or permanent residents.

Foreign Students & Scholars

OIE serves as the liaison to the university for all non-immigrant students and scholars. The foreign student and scholar advisors counsel on immigration/visa, academic, personal, social and acculturation matters. Additional services include workshops in partnership with other offices on cultural

adjustment, international career planning and tax filing. OIE supports international student groups, partners and family members with resources and programming that assist with acclimating to the broader community.

Study Abroad

Over 600 Carnegie Mellon students, from all majors, study abroad annually. With careful planning, students may study abroad for a semester, academic year or during the summer in various countries around the world, including Carnegie Mellon's campus in Doha, Qatar. A well planned study abroad program will allow a student to receive credit for study abroad and graduate on time. There are additional opportunities for short-term, non-credit study abroad experiences. Many students are able to use their Carnegie Mellon funding for study abroad. The study abroad staff assist students in all stages of the process of going abroad. The advisors promote study abroad, advise students, work with the academic departments and conduct information sessions, pre-departure orientations and welcome back workshops. For more detailed information about Carnegie Mellon's study abroad program, see the Undergraduate Options (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studyabroadtext>) section of this catalog or visit www.cmu.edu/studyabroad (<http://www.cmu.edu/studyabroad/>).

Student Affairs

Gina Casalegno, Vice President for Student Affairs & Dean of Students
Location: Warner Hall 321, 5000 Forbes Avenue, Pittsburgh, PA 15213
Phone: 412-268-2075

www.cmu.edu/student-affairs/ (<http://www.cmu.edu/student-affairs/>)

The Division of Student Affairs is available to support and foster student intellectual and personal growth and help students explore and experience the different aspects of college life. We care about you, your studies, your social growth, your well-being and your future and want to help you enjoy a great Carnegie Mellon experience.

Central to our success is a commitment to cultivating deep and meaningful one-to-one relationships with students. We build and sustain collaborative relationships throughout the university to best serve the needs of our student body. Programs, services, and efforts are dedicated to the development of an engaged community among students, faculty, staff and alumni where meaningful and authentic exchanges are valued. Division of Student Affairs staff help students navigate and reflect upon challenges and transitions, and we empower them to become architects of their own learning and development.

The Office of the Dean of Students provides central leadership of metacurricular experience at Carnegie Mellon, including divisional strategic planning, coordination of student support and crisis intervention, and facilitation of divisional assessment.

Student Affairs is comprised of the following offices and departments, which offer services aimed at enhancing the student experience at CMU.

Athletics, Physical Education and Recreation

Josh Centor, *Director & Associate Vice President*

Location: Skibo Gym 204, Frew St. & Tech St, Pittsburgh, PA 15216

Phone: 412-268-8054

<http://athletics.cmu.edu> (<http://athletics.cmu.edu/landing/index/>)

The Department of Athletics, Physical Education and Recreation has a transformative impact through divers programs that inspire leadership, teamwork, wellness and resilience, and offers students, staff and faculty opportunity to develop intellect, ethics and character needed to lead meaningful lives while impacting society in profound ways. View more information about Athletics, Physical Education and Recreation (p. 54).

Career and Professional Development Center

Kevin Monahan, *Director & Associate Dean of Student Affairs*

Location: West Wing, 2nd Floor, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-2064

career@andrew.cmu.edu

www.cmu.edu/career (<http://www.cmu.edu/career/>)

The Career and Professional Development Center (CPDC) is Carnegie Mellon University's centralized career services center providing a comprehensive range of services, programs and materials focusing on career exploration and decision making, professional development, experiential learning and employment assistance to meet today's evolving workplace and student goals of finding satisfying work.

Students wishing to explore how majors and minors relate to career choice, as well as gain information about particular fields, will work with a career consultant to examine their skills, interests, and values and how they relate to various career fields. Career consultants also coach students in writing resumes and cover letters, networking, locating internship and job opportunities, preparing for interviews, and pursuing graduate school opportunities. Career consultants are assigned to each college and provide individualized support, general career programming, and college-specific workshops. In addition to the workshops presented by the staff, consultants coordinate an annual professional development series presented by prominent alumni and recruiters in various industries and fields.

Handshake

Several thousand summer internships and professional full-time job opportunities are made available to Carnegie Mellon students through Handshake, an online job listing resource. Students can access Handshake through the center's homepage and can also use the service to search for student employment and on-campus jobs. Handshake also provides information on the hundreds of employers that visit our campus each year. These organizations interview students for internships and professional employment, as well as hold informational sessions in the evenings that are open to the entire campus.

Center for Student Diversity and Inclusion

M. Shernell Smith, *Executive Director*

Location: Cohon University Center, Lower Level, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-2150

[C \(ocsi@andrew.cmu.edu\)](mailto:ocsi@andrew.cmu.edu)SDI@andrew.cmu.edu (CSDI@andrew.cmu.edu)

www.cmu.edu/student-diversity (<https://www.cmu.edu/student-diversity/>)

The Center for Student Diversity and Inclusion actively cultivates a strong, diverse and inclusive community capable of living out these values and advancing research, creativity, learning and development that changes the world.

The Center offers resources to enhance an inclusive and transformative student experience in dimensions such as access, success, campus climate and intergroup dialogue. Additionally, the Center supports and connects historically underrepresented students and those who are first in their family to attend college in a setting where students' differences and talents are appreciated and reinforced.

Cohon University Center

Marcia Gerwig, *Director*

Location: Cohon University Center 103, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-2107

infodesk@andrew.cmu.edu

www.cmu.edu/cohon-university-center (<https://www.cmu.edu/cohon-university-center/>)

Designed to support health, wellness, and community engagement, the Cohon University Center offers conference space and meeting rooms, a studio theater, a state-of-the-art fitness center, gymnasium, swimming pool, multiple dining locations, and plenty of gathering and study space.

Community Health and Well-being

Maureen Dasey-Morales, *Associate Vice President*

Location: Warner Hall 321, 4910 Forbes Ave, Pittsburgh, PA 15213

www.cmu.edu/wellbeing/ (<https://www.cmu.edu/wellbeing/>)

Community Health and Well-Being at CMU encompasses the following departments and initiatives: Counseling & Psychological Services, Religious & Spiritual Life Initiatives, Student Support Resources, University Health Services, and Wellness Initiatives. The Community Health and Well-Being services are also supported by departments like Athletics and Recreation, the Center for Student Diversity and Inclusion, the office of Student Leadership, Involvement, and Civic Engagement, the Student Academic Success Center and many more. During your time at CMU, Community Health and Well-being is here to support and help you discover what well-being means for you. We have a lot of people who care and a lot of resources to help. All of these people and resources are organized into the Community Health and Well-being website (<https://www.cmu.edu/wellbeing/>). This website is a space for you to explore the various components of well-being and the opportunity for you to make any or all of it a part of your well-being journey.

Office of Community Standards and Integrity

Lenny Chan, *Director*

Location: Morewood Gardens, 1060 Morewood Ave, Pittsburgh, PA 15213

Phone: 412-268-2140

ocsi@andrew.cmu.edu

www.cmu.edu/student-affairs/ocsi (<https://www.cmu.edu/student-affairs/ocsi/>)

The Office of Community Standards and Integrity (OCSI) is staffed by an experienced team of professionals dedicated to the growth and development of students both in and outside of the classroom. When faced with a challenging or complicated situation, the OCSI can serve as a resource for students, staff, faculty, and family members looking for guidance. Our staff strives to be approachable, knowledgeable, and current with best practices in the field of student conduct and academic integrity. The heart of our work is rooted in the value and support of our campus community members. We welcome inquiries regarding educational programming, student support, and guidance with the university's student conduct and academic integrity processes.

Counseling and Psychological Services

Shane Chaplin, *Executive Director*

Location: Morewood Gardens E-Tower, Pittsburgh, PA 15213

Phone: 412-268-2922

www.cmu.edu/counselin (<http://www.cmu.edu/counseling/>)g (<https://www.cmu.edu/counseling/>)

Counseling and Psychological Services (CaPS) addresses the mental health needs of the university community by providing treatment to students and collaborating with staff, faculty and family members. CaPS helps students improve their psychological health by facilitating insight and fostering deeper understanding of their personal struggles needed to make better choices for themselves. Services at CaPS are developmental in nature, aimed at supporting students in the moment and in their personal growth and maturation over time.

CaPS is attentive to issues of diversity and equality. We respect and value each person as a unique individual. We offer a safe and supportive space for students who identify as LGBTQ+ to navigate the challenges of exploring and integrating their gender and sexual identities.

Confidential services for students include consultation, short-term individual psychotherapy, crisis support and psychiatric referral when appropriate. Our staff provides consultation and education for students, faculty, staff and family members to address concerns regarding the well-being of a student, and questions about our services or psychological treatment.

CaPS staff also provide training and education for students and staff in support roles (i.e., advisors, RAs, OCs).

Dining Services

Joseph Beaman, *Director*

Location: Residence on Fifth, 4700 Fifth Ave, Second Floor Pittsburgh, PA 15213

Phone: 412-268-2139

dining@andrew.cmu.edu

www.cmu.edu/dining (<https://www.cmu.edu/dining/>)

Carnegie Mellon Dining Services offers a diverse portfolio of dining destinations, enriches and nourishes lives, and enhances the CMU transformative experience for students. We are always looking for new ways to improve CMU's dining experience.

Family & Parents

Lauren Moran, *Associate Dean for Parent & Family Engagement and First-Year Orientation*

Location: 1060 Morewood Gardens, Pittsburgh, PA 15213

Phone: 412-268-2142

parents (parents@andrew.cmu.edu)@andrew.cmu.edu

(career@andrew.cmu.edu)

www.cmu.edu/parents (<https://www.cmu.edu/parents/>)

We encourage our students to develop independence and the life skills necessary to successfully navigate their personal affairs as young adults. We also know that family plays an important role and are key partners in our students' success. We're here to share information about general campus resources, important events and developmental milestones in your student's experience so that you have information to facilitate meaningful interactions with your student about their Carnegie Mellon journey.

First-Year Orientation

Lauren Moran, *Associate Dean for Parent & Family Engagement and First-Year Orientation*

Location: 1060 Morewood Gardens, Pittsburgh, PA 15213

Phone: 412-268-2142

orientation@andrew.cmu.edu

www.cmu.edu/first-year-orientation (<https://www.cmu.edu/first-year-orientation/>)

Orientation & First-Year Programs is responsible for providing vision and leadership for a comprehensive approach to new student orientation and transition programs. The office provides programs, opportunities and services to help students and family members successfully transition to the Carnegie Mellon community.

The office is responsible for program, development, marketing and implementation of orientation and transition programs. Areas of concentration include new student orientation, parent's programming such as Family Weekend, freshman programming series, and special event planning.

Housing Services & Residential Education

Tera Monroe, *Associate Dean & Director of Residential Education*

Housing Location: Residence on Fifth, 4700 Fifth Ave, Second Floor, Pittsburgh, PA 15213

Residential Education Location: Morewood Gardens, Student Life Suite, 1060 Morewood Ave, Pittsburgh, PA 15213

Phone: 412-268-2139 (Housing), 412-268-2142 (Residential Education)

housing@andrew.cmu.edu, resed@andrew.cmu.edu

www.cmu.edu/housing (<https://www.cmu.edu/housing/>)

The residential experience at Carnegie Mellon embraces all aspects of a student's life. Together, Housing Services and the Office of Residential Education create a lived experience that supports, engages, and inspires students throughout their university experience. It's the place they call home, the place where they will learn more about themselves, their community, and the world around them. Within a 24/7 community of support, staff and residents build meaningful relationships that inspire exploration, growth, and learning.

Pre-College Summer Programs

Beth Yazemboski, *Senior Director of Pre-College Programs*

Location: Residence on Fifth, 5000 Forbes Ave, Pittsburgh, PA 15213

Phone: 412-268-5914

Email: precollege@andrew.cmu.edu (pc-life@andrew.cmu.edu)

Website: www.cmu.edu/pre-college (<https://www.cmu.edu/pre-college/>)

Our Pre-College Summer Programs for high school rising juniors and seniors will show you what life at Carnegie Mellon is about - from the classroom to what's happening on weekends. You'll meet people from all over the world, be inspired by our world-renowned faculty, take part in the excitement of campus and have the opportunity to explore the city of Pittsburgh.

Religious and Spiritual Life Initiatives

Location: 5000 Forbes Ave, Pittsburgh, PA 15213

www.cmu.edu/student-affairs/spirituality (<https://www.cmu.edu/student-affairs/spirituality/>)

Carnegie Mellon is committed to the holistic growth of our students, including creating opportunities for spiritual and religious practice and exploration for individuals all along the spectrum of spiritual and religious development. Carnegie Mellon encourages an exploratory mindset for all students - creating programs and resources for students to pause, engage in self-inquiry, and to reflect upon and articulate one's moral fabric.

Additionally, we offer programs and initiatives that cross traditional religious boundaries to increase our students' knowledge of and appreciate for the full diversity of the world's religious and spiritual traditions.

Office of Student Leadership, Involvement, and Civic Engagement

Elizabeth Vaughan, *Director & Associate Dean of Student Affairs*

Location: Cohon University Center, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-8704

slice@andrew.cmu.edu

www.cmu.edu/student-affairs/slice/ (<https://www.cmu.edu/student-affairs/slice/>)

The Office of Student Leadership, Involvement, and Civic Engagement (SLICE) complements students' academic experiences by providing services and resources that engage students in creating campus culture through social, cultural, intellectual, spiritual, athletic, recreational, artistic, political, and service opportunities. Our staff is committed to delivering quality advising, resource materials, leadership development opportunities, and administrative support services to impact students' growth and development and enhance the success of each student organization.

Our office partners with students to create a vibrant culture of student life on the Carnegie Mellon campus. Our community is home to nearly 250 recognized student organizations that are supported by the Student Activities staff team. In addition to serving as individual advisors to many organizations and providing resources, support, and ad hoc advising to all student organizations, our office also coordinates a slate of opportunities to help Carnegie Mellon students get involved in campus life.

Student Support Resources

Bryan Koval, *Director*

Location: Warner Hall 321, 4910 Forbes Ave, Pittsburgh, PA 15213

Phone: 412-268-2075

www.cmu.edu/wellbeing/resources/student-support-resources/ ([https://](https://www.cmu.edu/wellbeing/resources/student-support-resources/)

www.cmu.edu/wellbeing/resources/student-support-resources.html)

The Student Support Resources team offers an additional level of support and expertise for students who are navigating any of a wide range of life events. Student Support Resources staff members work in partnership with campus and community resources to provide coordination of care and support appropriate to each student's situation.

University Health Services

Christine Andrews, *Executive Director*

Location: 1060 Morewood Ave., Pittsburgh, PA 15213

Phone: 412-268-2157

health@andrew.cmu.edu

www.cmu.edu/health-services/ (<https://www.cmu.edu/health-services/>)

Student Health Services is staffed by physicians, advanced practice clinicians, registered nurses, and professional staff who provide medical care, health promotion and insurance services. A list of current services and fees may be found on the University Health Services website (<https://www.cmu.edu/health-services/services-and-fees/>).

Patients are seen by appointment; however, walk-in urgent care is provided. Appointments may be made by calling the office.

HEALTH INSURANCE

In addition to providing medical care, University Health Services administers the Student Health Insurance Program, which offers a high level of coverage in a wide network of health care providers and hospitals. It also covers most of the fees for care at Student Health Services. All full-time students are required to carry health insurance and will be assessed a charge for the individual basic mandatory plan offered through the university student health insurance program. The charge will appear on the invoice of the first semester of attendance in the academic cycle. The student is required to take one of the following three actions: (1) enroll in the basic plan as charged; (2) upgrade the benefit plan by enrolling in the enhanced student health insurance options during the open enrollment period; (3) apply for a waiver from the mandatory plan if covered by family/other insurance.

Wellness

Angie Lusk, *Program Director for Student Affairs Wellness Initiatives*

Location: Cohon University Center, 111E, 5032 Forbes Ave, Pittsburgh, PA 15213

Phone: 412-268-2142

alusk@andrew.cmu.edu

www.cmu.edu/wellness/ (<https://www.cmu.edu/wellness/>)

We believe our individual and collective well-being is rooted in healthy connections, to each other and to campus resources. How we care for ourselves and others is important to our success. There are a wide variety of resources, opportunities, and people that want to help you thrive inside and outside of the classroom. Every voice matters as we continually enhance the quality of life for students, faculty, and staff and community partners. Join us in our shared commitment to engage and to empower.

Undergraduate Options

This section of the catalog introduces some of the options that undergraduate students can choose from to supplement their degree program, advance their career objectives, or focus on an interest that may be unrelated to their major. From IDeATe, which offers minors and courses in areas that merge technology and creativity like Game Design, to Student Defined Majors, which is designed for students whose academic goals cannot be adequately served by curricula of existing majors or minors, learn more about the additional options offered to CMU's undergraduate students.

Additional Majors/Dual Degrees

Students interested in pursuing more than one area of study are encouraged to consider an additional major or dual degree. Students who complete an additional major will earn a single degree in two areas. Generally, it is possible to fulfill the requirements of both majors in four years by taking the course requirements of the second major in the elective spaces allowed by the first major.

Some majors are offered only as additional majors:

- Students in the College of Engineering may elect to double major in Biomedical Engineering (p. 77) or Engineering and Public Policy (p. 130), which are offered only as an additional major.
- Students from any college may pursue an additional major in Human-Computer Interaction (p.), Science, Technology and Public Policy (p. 131), or Robotics (p.).

Dual Degree programs allow students to earn two degrees. Students who are interested in an additional major or dual degree are encouraged to review the specific possibilities with the relevant academic advisor.

Accelerated Master's Programs

Qualified undergraduates may apply to one of several programs to earn their bachelor's and master's degrees in five years. For further details about these programs, please refer to the appropriate college or departmental sections.

College of Engineering

The five-year Integrated Master's/Bachelor's programs offered by the Departments of Electrical and Computer Engineering and Civil and Environmental Engineering offers students superior technical preparation for careers in industry. The Departments of Chemical Engineering and Mechanical Engineering also offer fifth-year Accelerated Master's programs. The Department of Materials Science and Engineering offers a cooperative Industrial Internship Option in which students alternate coursework with practical experience in industry. Admission is highly competitive and leads to a Master of Science degree.

Dietrich College of Humanities and Social Sciences

The Department of Philosophy offers two bachelor's/master's degree options: the Bachelor's in Logic and Computation and Master's in Logic, Computation & Methodology degree as well as a Bachelor's/Master's degree in Philosophy. The Institute for Politics and Strategy offers an accelerated Master of Science degree in International Relations and Politics. The Master of Arts in Teaching English to Speakers of Other Languages (TOESL) is a fifth-year master's option for Modern Language students who are concentrating in English as a Second Language. Also, the Department of English offers an accelerated program for undergraduates to obtain a Master of Arts in Professional Writing.

Heinz College of Information Systems and Public Policy

Heinz College's Accelerated Master's program allows qualified undergraduate students to earn a prestigious Master of Science degree in Public Policy and Management. For students in the College of Fine Arts or the Bachelor of Humanities and Arts degree program who are interested in careers in arts management, the program leads to a Master of Arts Management degree.

Mellon College of Science

The Honors Programs in the Departments of Chemistry and Mathematics are demanding, accelerated programs that give highly qualified students the

opportunity to earn their bachelor's and master's degrees in just four years. Admission is by invitation only.

Tepper School of Business

Students who are interested in business management may wish to consider the Tepper School of Business 3-2 program. Qualified undergraduate students may earn their Master of Business Administration in addition to their bachelor's degree.

Health Professions Program

Jason D'Antonio, PhD, *Director*

Location: Doherty Hall 1320

Phone: 412-268-8494

The Health Professions Program (<http://www.cmu.edu/hpp/>) (HPP) at Carnegie Mellon University is an advising resource for all university students and alumni who are interested in a career in the health professions. This program complements a student's curricular advising and is meant to help students explore their interests, prepare for graduate programs in the health professions, and facilitate their application process. Students can enroll in the program at any time during their academic career, but the importance of early planning is communicated to interested first-year students. Once enrolled, students meet regularly with the director to discuss course requirements, medical exposure opportunities, and other aspects of preparing to be a competitive candidate.

Students in the HPP span all colleges of the university and have many diverse career interests including medicine, dentistry, optometry, biomedical research, medical physics, biomedical engineering, public health, medical informatics, and health policy.

For students interested in medicine or dental medicine, regardless of a student's major, the basic course requirements outlined below must be completed prior to matriculation:

1. One year of Biology with one lab, plus Biochemistry.

This is typically fulfilled by the following Carnegie Mellon courses:

| | | |
|-----------|--|------|
| 03-121 | Modern Biology | 9-10 |
| or 03-151 | Honors Modern Biology | |
| 03-135 | Structure and Function of the Human Body | 9 |
| or 42-202 | Physiology | |
| or 03-220 | Genetics | |
| or 03-320 | Cell Biology | |
| 03-124 | Modern Biology Laboratory | 9-12 |
| or 03-343 | Experimental Techniques in Molecular Biology | |
| or 03-206 | Biomedical Engineering Laboratory | |
| or 02-261 | Quantitative Cell and Molecular Biology Laboratory | |
| 03-231 | Honors Biochemistry | 9 |
| or 03-232 | Biochemistry I | |

2. One year of Inorganic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

| | | |
|-----------|---|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-207 | Techniques in Quantitative Analysis (non-Chem majors) | 9 |
| or 09-221 | Laboratory I: Introduction to Chemical Analysis | |

3. One year of Organic Chemistry with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

| | | |
|-----------|--------------------------|------|
| 09-217 | Organic Chemistry I | 9-10 |
| or 09-219 | Modern Organic Chemistry | |

| | | |
|-----------|--|------|
| 09-218 | Organic Chemistry II | 9-10 |
| or 09-220 | Modern Organic Chemistry II | |
| 09-208 | Techniques for Organic Synthesis and Analysis (non-Chem majors) | 9 |
| or 09-222 | Laboratory II: Organic Synthesis and Analysis | |

4. One year of Physics with one lab.

This is typically fulfilled by the following Carnegie Mellon courses:

| | | |
|-----------|---|-----|
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| or 33-142 | Physics II for Engineering and Physics Students | |
| 33-100 | Basic Experimental Physics | 6-9 |
| or 33-104 | Experimental Physics | |

5. One year of Math.

| | | |
|-----------|---|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| or 21-124 | Calculus II for Biologists and Chemists | |
| or 36-200 | Reasoning with Data | |
| or 36-202 | Methods for Statistics & Data Science | |

6. One year of English.

This is typically fulfilled by the following Carnegie Mellon courses:

| | | |
|--------|---|---|
| 76-101 | Interpretation and Argument (or any two of 76-106/778) | 9 |
| 76-xxx | English course of the student's choice, typically 200-level or higher | |

In addition to these general course requirements, recommended coursework includes statistics, behavioral sciences, ethics, and languages. Interdisciplinary studies are also strongly encouraged, and many students design an undergraduate curriculum that incorporates majors and/or minors in both the natural and social sciences.

Participating in research is a hallmark of the educational experience at Carnegie Mellon in many disciplines. Whether in the psychology lab studying the impact of breast cancer diagnosis on family social dynamics, in the NMR lab imaging metabolic function in the heart or brain, or in the surgery suite testing robotic devices, our students have made significant achievements in research. Health Professions programs are interested in applicants who have experience with the scientific method and who are intellectually curious about biomedical science, social science, biomedical engineering, as well as public health, epidemiology, and the social determinants of health.

Our university policy is to train students to be first class scientists, engineers, artists, writers, managers, or whatever their passion may be. We do not train students to be "pre-med," but if they choose to use their talents in a health profession, we offer many services to help them obtain their life goals. Regular advising, application workshops, health issue seminars and symposium, community outreach activities, and preceptorship/ internship experiences are all part of our programming. The student pre-health organizations on campus: Doctors of Carnegie Society (DOCS); Student Diversity Inclusion Committee (SDIC); Alpha Epsilon Delta (AED); Global Medical Brigades; and Global Public Health Brigades, together with the HPP, provide students with opportunities to learn, explore, and prepare for their chosen area of professional interest.

The HPP has been successful in helping students to define, prepare for, and obtain their professional goals. Our students are regularly accepted at top-level medical, dental and graduate programs, and our alumni continue to serve as outstanding ambassadors of Carnegie Mellon.

IDeATe

The Integrative Design, Arts and Technology (IDeATe) (<http://ideate.cmu.edu>) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in the IDeATe labs and classrooms based in Hunt Library. The program addresses current and emerging real-world challenges that require disciplinary expertise

coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten interrelated areas, all of which can be shaped into minors that students pursue alongside their primary majors. The themes of these areas integrate knowledge in technology and arts:

- **Game Design:** Design compelling game experiences and enhance your knowledge of key components of game design such as systems and mechanics, dramatic narrative and character development, programming and engine development, user testing and iterative development. Create games for a variety of audiences, including mobile applications, virtual reality platforms and even tabletop games.
- **Animation & Special Effects (p. 714):** Explore the technical and artistic aspects of 3D and 2D animation in an integrated manner and within different application contexts—from film animation and visual effects to interactive displays.
- **Media Design:** Design digitally mediated experiences across various platforms, from mobile devices to large-scale installations, and for varied applications—from media for daily living to mediated performances).
- **Design for Learning:** Explore the art and science of designing engaging learning experiences that creatively merge technology, learning sciences, and media arts know-how. Create inclusive learning media experiences ranging from mobile games to interactive museum exhibits, augmented classrooms, and adaptive ed-tech.
- **Sonic Arts:** Create experimental music and explore emerging applications and markets for sound design, music creation, and performance.
- **Innovation and Entrepreneurship:** Work collaboratively in hands-on explorations of the problems, opportunities, strategies, and circumstances that lead to innovations. You will experience integrated models of innovation that increase the likelihood of successful products and services that will bring value to society and/or the marketplace.
- **Intelligent Environments:** Design and implement interactive 3D spaces—both physical and virtual—that shape our experience of time and space.
- **Physical Computing:** Build interactive devices combining small programmable electronic controllers with physical embodiments, adding on-board processing and reactivity to nearly anything around you. Create novel games, useful devices, experimental provocations, and more.
- **Soft Technologies:** Weave together a rich set of traditions and experimental techniques to animate soft materials and matter.
- **Immersive Technologies in Arts & Culture:** Blend technological skills with creative imagination and critical humanistic practice.

Individuals who make significant contributions, academically and professionally, in these areas are solidly prepared in a related discipline. Their preparation is combined with the ability to work in multidisciplinary teams that span technology and the arts. IDeATe serves as a multidisciplinary collaborative learning addition to the education (and learning outcomes) that students receive through their disciplinary major rather than a standalone learning experience.

Innovation and advancement in the IDeATe areas, as in many complex areas of inquiry, is the result of collective inquiry and requires deep expertise in all contributing areas of knowledge (i.e., expert technologists and artists). Carnegie Mellon is the only university in the United States with highly ranked departments in key technological and artistic domains. With these resources, Carnegie Mellon is uniquely positioned to create faculty and student teams that contain all necessary, high-level expertise in tech-arts areas of inquiry.

Students who participate in IDeATe will be able to combine the unique experience of a "deep dive" in their chosen discipline while connecting to the diverse areas of knowledge and skill across the university. To help facilitate this experience, the educational objectives of the IDeATe network are:

- Students from any undergraduate major can integrate a tech-arts area of study into their curricular plan through the IDeATe minors, which enhance and synthesize the tech-arts ecosystem at CMU.
- Students in IDeATe have the opportunity to:
 - Immerse themselves in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology
 - Engage in active "learning by doing" in shared labs and maker spaces
 - Address current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and integrative approaches.

Across the ten IDeATe areas, there are over 50 multi-disciplinary technology-arts courses that a student can choose from to customize their paths. Students are assisted in their choice of courses and minor by a dedicated IDeATe advisor who works in tandem with the advisor in their home department.

The IDeATe Portal Courses introduce students to the concepts and practices of knowledge areas beyond their discipline that contribute to the subject of each minor/concentration. After completing the portal courses, students should be able to (1) interpret cross-disciplinary communication from their collaborators (and use that interpretation productively in the collaborative work), (2) translate their own disciplinary expertise to describe ideas and outcomes in a way their cross-disciplinary collaborators can understand, and (3) develop interdisciplinary tech-arts prototypes (that include perspectives from multiple disciplines and enable further interdisciplinary communication and collaboration).

The remaining courses of IDeATe deepen exploration in a given area. Each course is focused on a key aspect of the area that it is categorized under. By taking these courses, the student can become familiar with many of the technical and creative issues in the area of the minor and the collaborative processes they entail. These courses are collaborative because they promote hands-on learning through making, critique, and iterative design and they promote learning from both the instructor and the interdisciplinary peer cohort. At the conclusion of each course a student should be in a position to collaboratively plan and implement an established outcome in the area within a limited amount of time and apply skills from both technology and arts disciplines to prototype ideas and leverage the diversity of perspectives to produce innovation in the field.

A completion of a minor should provide multidisciplinary training in the area of the concentration and furthermore *enhance collaborative learning experience and skills of students*: diversify the cohorts of the student, enhance collaboration skills, promote cognitive versatility, facilitate skill transfer across technology and the arts, and produce graduates that can innovate in 21st century creative industries.

For more information, please visit the IDeATe website (<https://ideate.cmu.edu>).

Minors

In addition to a student's primary degree, they can choose a minor that is a secondary focus to the student's area of study, which can enhance a student's breadth of study and overall experience while not requiring the same amount of coursework as a second major or degree. The following list shows available minors. Unless otherwise indicated, minors are generally open to all university undergraduate students.

Intercollege:

- Game Design (IDeATe) (p. 886)
- Health Care Policy and Management (p. 888) (jointly between the Dietrich College of Humanities and Social Sciences, the H. John Heinz III College, and Mellon College of Science)
- Immersive Technologies in Arts & Culture (p. 443) (IDeATe and Department of Modern Languages)
- Music Technology (p. 297) (jointly between the School of Music and School of Computer Science)
- Neural Computation (p. 719) (jointly between the School of Computer Science, Mellon College of Science, and Dietrich College of Humanities and Social Sciences)

College of Engineering:

The following engineering minors are open to all Carnegie Mellon students:

- Biomedical Engineering (p. 173)
- Engineering Studies (p. 173)
- Technology and Policy (p. 173)

Designated Minors (open only to engineering students):

- Additive Manufacturing (p. 176)
- Audio Engineering (p. 177)
- Automation and Controls (p. 178)
- Colloids, Polymers and Surfaces (p. 178)
- Electronic Materials (p. 178)
- Global Engineering (p. 179)
- Materials Science and Engineering (p. 179)
- Mechanical Behavior of Materials (p. 179)

College of Fine Arts:

- Architectural Design Fabrication (p. 188) (available only to B. Arch candidates)
- Architectural Representation and Visualization (p. 188) (available also to B. Arch candidates)
- Architectural Technology (p. 188)
- Architecture (p. 188)
- Architecture History (p. 188) (available also to B. Arch candidates)
- Art (p. 189)
- Building Science (p. 188) (available only to B. Arch candidates)
- Collaborative Piano (p. 189) (available only to Piano majors in the School of Music)
- Conducting (p. 297) (available only to students in the School of Music)
- Design (p. 191)
- Drama (p. 191)
- History of the Arts (p. 189)
- Media Design (p. 189) (IDeATe)
- Music (p. 192)
- Music Education (p. 297) (available only to students in the School of Music)
- Music Technology (p. 297)
- Music Theory (p. 297)
- Musicology (p. 192)
- Photography (p. 193)
- Sonic Arts (p. 192) (IDeATe)
- Sound Design (p. 297) (IDeATe)

Dietrich College of Humanities and Social Sciences:

- African and African American Studies (p. 563)
- Anthropology (p. 388)
- Arabic Studies (p. 443)
- Behavioral Economics, Policy and Organizations (p. 520)
- Chinese Studies (p. 443)
- Cognitive Neuroscience (p. 502)
- Creative Writing (p. 344)
- Cybersecurity and International Conflict (p. 421)
- Decision Science (p. 522)
- Economics (p. 522)
- English (p. 344)
- Ethics (p. 481)
- Film and Media Studies (p. 563)
- French and Francophone Studies (p. 443)
- Gender Studies (p. 564)
- German Studies (p. 443)
- Hispanic Studies (p. 443)
- Humanities Analytics (p. 344)
- International Relations and Politics (p. 422)
- Japanese Studies (p. 443)
- Linguistics (p. 565)
- Literature & Culture (p. 344)
- Logic and Computation (p. 481)
- Military Strategy and International Relations (p. 423)
- Philosophy (p. 481)
- Policy and Management (p. 522)
- Politics and Public Policy (p. 423)
- Professional Writing (p. 344)
- Psychology (p. 502)
- Rationality, Uncertainty, and Choice: Formal Methods (p. 481)
- Religious Studies (p. 567)
- Russian Studies (p. 443)
- Science, Technology and Society (p. 568)
- Social & Political History (p. 388)
- Societal & Human Impacts of Future Technologies (SHIFT) (p. 481)
- Sociology (p. 569)
- Statistics (p. 546)
- Technical Writing (p. 344)

Mellon College of Science:

- Biological Sciences (p. 594)
- Chemistry (p. 621)
- Computational Finance (<http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/#majorminorincomputationalfinancetext>)
- Discrete Mathematics and Logic (p. 646)
- Environmental and Sustainability Studies (p. 676)
- Mathematical Sciences (p. 646)
- Neuroscience (p. 594)
- Physics (p. 665)
- Scientific Computing (p. 676)

School of Computer Science:

- Animation & Special Effects (p. 714) (IDeATe)
- Artificial Intelligence (p. 692)
- Computational Biology (p. 696)
- Computer Science (p. 702)
- Design for Learning (IDeATe) (p. 714)
- Human-Computer Interaction (p.)
- Intelligent Environments (p. 714) (IDeATe)
- Language Technologies (p. 717)
- Machine Learning (p. 718)
- Physical Computing (p. 714) (IDeATe)
- Robotics (p.)
- Software Engineering (p. 720)

Tepper School of Business:

- Business Administration (p. 843)
- Business Analytics and Optimization (p.)
- Innovation and Entrepreneurship (p.) (IDeATe)
- Operations and Supply Chain Management (p.)

Pre-Law Advising Program

Director: Joseph Devine, *Associate Dean for Undergraduate Studies, Dietrich College*

Location: Dietrich College Dean's Office, Baker Hall 154
www.cmu.edu/pre-law (<http://www.cmu.edu/pre-law/>)

"Law School" is an objective that students frequently mention when asked about post-baccalaureate plans. It seems in its brevity to be a simple enough answer, but in reality it masks a host of complex and momentous personal decisions and strategic tasks.

First and foremost, seeking entry into law school implies an informed decision about the rigors of law school and the realities of professional life as an attorney, as well as a strong and mature commitment to achieving these objectives at significant cost and investment (financial, personal, and intellectual). Second, it implies an understanding of the prolonged sequence of steps involved in the process of selecting law schools to which to apply, actually applying, ultimately selecting a school to attend, financing a law school education, and succeeding in law school. Finally, it implies an understanding of this as one of many options that should be carefully considered before a choice is made that will so significantly influence the course of one's personal and professional life.

To address these needs, the university offers a pre-law advising program for students and alumni who are contemplating or actively seeking to enter law school. The program consists of a range of support services, coordinated centrally, designed to assist these groups in engaging the complex questions associated with decisions about law school, and in successfully negotiating the sequence of tasks associated with selecting, applying and gaining admission to the best law schools possible.

The emphases of this program are:

- early identification of pre-law candidates;
- stimulation at early stages and throughout this process to consider the essential questions of personal suitability for law school and professional life as an attorney;
- engagement with meaningful substantive issues rooted in the law that illustrate the intellectual complexities of our legal system and the corresponding intellectual acumen needed to enter and thrive in this profession;

- timely direction in designing and executing a well-planned law school research, selection and application strategy;
- gathering and using accurate data on university alumni entering law school and the legal profession.

The program proper consists of several components, organized and made available as an ongoing service to all students and graduates of the university. These components include periodic workshops and seminars, a pre-law website, a pre-law newsletter, and linkage with law school admissions offices, the Law School Admissions Council, and associations (both regional and national) of pre-law advisors. The program also works closely with the student Pre-law Society.

Student Defined Majors

Carnegie Mellon offers the opportunity for undergraduate students to pursue a Student Defined Major. Some colleges have specific processes for Student Defined Majors within their college (see relevant college section of the catalog). For information and advice, interested students are encouraged to speak to the associate dean of their current home college or the college most relevant to the proposed course of study.

The requirements for successful completion of a Student Defined Major include a student proposal approved by an advisor, relevant college(s), the vice provost for education, and successful completion of the approved course of study. In brief:

- A student interested in pursuing a student-defined major must develop a proposal which outlines an intellectually coherent area of study (with degree title) and a plan of study (courses to be taken, pedagogical rationale, and proposed schedule). The proposal should include an explanation of why it is not appropriate or possible to pursue such a program through the curriculum of any one of the colleges. It should outline a program of study for both general education (for example, the core requirements of one of the most relevant colleges or equivalent general education plan) and major requirements. The proposal should designate one of the participating colleges as de facto "home college" for tracking and verification purposes.
- **Proposals must be approved at least one academic year prior to expected graduation.** Students should therefore submit their proposals by the end of their fifth semester, to allow ample time for approval.
- The student's proposal must be approved by a faculty advisor within a college who takes pedagogical responsibility for the program, by the de facto "home college" and by any other colleges involved in granting the degree. The signed proposal will be submitted to the Provost's Office for a final review and approval.
- Once approved by the faculty advisor, colleges, and the Provost's Office, the student's major will be administered by the advisor and their progress tracked by the dean's office of the "home college." The "home college" will be responsible for monitoring the student's progress and reminding any collateral colleges of the approval of the Student Defined Major so that these colleges may insure the student's ability to enroll in the necessary courses. Upon successful completion of the course of study, the "home college" will be responsible for contacting all the relevant colleges and verifying the completion of the degree. Upon consultation with the "home college", students may receive their diploma in the most relevant department's ceremony.

Note: To distinguish Student Defined Majors from regularly offered majors at Carnegie Mellon, the phrase "(Student Defined Major)" will be added to the end of the major name. This notation will appear on all official documents (transcripts, verification letters, diplomas, etc.).

Student-Taught Courses (StuCo)

The Student College (StuCo) was established in 2001 to provide Carnegie Mellon students with the opportunity to share knowledge through educational, self-designed courses. Students can teach classes on any topic of their choice. However, the course cannot be available through regular university offerings. Courses typically meet once a week (for a full semester) and follow the current Carnegie Mellon academic calendar. Instructors and students receive credit (3 elective units - pass/no pass) for their work.

- All CMU students are eligible to teach StuCo courses and to join the Executive Committee that governs StuCo.
- All currently-enrolled CMU students, staff and community members are eligible to take StuCo courses.
- StuCo classes are taught during the fall and spring semesters.

StuCo courses vary semester to semester. Current classes offered by StuCo for fall 2023 include:

| | | |
|--------|--|---|
| 98-012 | Student Taught Courses (StuCo): Fun with Robots | 3 |
| 98-026 | Student Taught Courses (StuCo): Genshin Impact: Team Building | 3 |
| 98-038 | Student Taught Courses (StuCo): Anime From Astro Boy to Your Name | 3 |
| 98-043 | Student Taught Courses (StuCo): Chess Tactics and Strategy | 3 |
| 98-044 | Student Taught Courses (StuCo): Introduction to Flag Design | 3 |
| 98-057 | Student Taught Courses (StuCo): Intro to Polytopes | 3 |
| 98-061 | Student Taught Courses (StuCo): UXplore: Uncover the Best of Modern UX Design | 3 |
| 98-097 | Student Taught Courses (StuCo): Intro to 3D Modeling- Character Design Pipeline | 3 |
| 98-099 | Student Taught Courses (StuCo): Problem Solving through Solving Problems | 3 |
| 98-122 | Student Taught Course (StuCo): Blackjack Techniques | 3 |
| 98-123 | Student Taught Courses (StuCo): Introduction to Hand Lettering | 3 |
| 98-128 | Student Taught Courses (StuCo): Fundamentals of Improv Comedy | 3 |
| 98-148 | Student Taught Courses (StuCo): Introduction to Student Journalism | 3 |
| 98-154 | Student Taught Courses (StuCo): Intro to Open-Source FPGA & ASIC Chip Design | 3 |
| 98-156 | Student Taught Course: Contemporary and Marginalized Poetics Workshop | 3 |
| 98-157 | Student Taught Courses (STUCO): Music: Deep-diving Artists and Genres | 3 |
| 98-179 | Student Taught Courses (StuCo): Introduction to Japanese Mahjong | 3 |
| 98-203 | Student Taught Courses (StuCo): Music and Interaction | 3 |
| 98-205 | Student Taught Courses (StuCo): Introduction to Minecraft | 3 |
| 98-226 | Student Taught Courses (StuCo): Movies You Should Have Watched By Now | 3 |
| 98-230 | Student Taught Courses (StuCo): Avatar: The Last Airbender & The Legend of Korra | 3 |
| 98-242 | Student Taught Courses (StuCo): Introduction to Esoteric Programming Languages | 3 |
| 98-244 | Student Taught Courses (StuCo): Sign Language Through Pop Music | 3 |
| 98-258 | Student Taught Courses (StuCo): Introduction to Competitive Pokemon | 3 |
| 98-266 | Student Taught Courses (StuCo): Private Pilot Ground School | 3 |
| 98-272 | Student Taught Courses (StuCo): Financial Literacy for Beginners | 3 |
| 98-288 | Student Taught Courses (StuCo): Star Wars: The Course Awakens | 3 |
| 98-301 | Student Taught Courses (StuCo): Taylor Swift Through the Eras | 3 |
| 98-303 | Student Taught Courses (StuCo): Introduction to Freestyle Rap | 3 |
| 98-309 | Student Taught Courses (StuCo): Build Your Own Startup | 3 |
| 98-317 | Student Taught Courses (StuCo): Hype for Types | 3 |
| 98-335 | Student Taught Courses (StuCo): Introduction to Glowstringing/Poi | 3 |
| 98-341 | Student Taught Courses (StuCo): Build Your Own Breadboard Computer | 3 |
| 98-369 | Student Taught Courses (StuCo): Brooklyn Nine-Nine | 3 |
| 98-374 | Student Taught Courses (StuCo): Steep by Steep: Investeagation into Tea Culture | 3 |
| 98-375 | Student Taught Courses (StuCo): Introduction to AI Alignment | 3 |
| 98-390 | They Came as Romans: Roman Civilization 360 | 3 |

For detailed information on the Student College, please visit the StuCo website (<http://www.cmu.edu/stuco/>).

Study Abroad Programs

Carnegie Mellon students from every major may be able to study in any part of the world for a semester, year or summer. Short-term programs during spring and winter break are also possible. A well planned study abroad program, in coordination with one's academic advisor, will allow a student to receive credit for study abroad and graduate on time. Most students study abroad during their junior year; however, a growing number of students are studying abroad during their sophomore and senior years.

The study abroad advising staff offers general information sessions as well as individual advising appointments to assist students in all stages of the study abroad process. The Office of International Education (OIE) also has useful web links to help students find the most appropriate study abroad program. In addition, OIE offers orientations to help with personal, academic and acculturation issues, before and after a study abroad experience.

Carnegie Mellon offers students a variety of payment options for study abroad to allow students to study abroad regardless of financial need. There are three categories of programs: Exchange Programs, Sponsored Programs, and External Programs. A description of each program follows.

More detailed information can be found at www.cmu.edu/studyabroad (<http://www.cmu.edu/studyabroad/>).

Exchange Programs

Students who participate in exchange programs pay Carnegie Mellon tuition and receive their regular financial aid package. Students are responsible for room, board, travel and miscellaneous expenses.

University Exchanges

Carnegie Mellon University has university-wide exchange programs with institutions located in Australia, Chile, Hong Kong, Israel, Japan, Mexico, Qatar, Singapore, and Switzerland.

Departmental Exchanges

Chemical Engineering, the College of Engineering, Design, Drama, Economics, Electrical and Computer Engineering, Heinz College, Computer Science and Business offer departmental exchange programs. Students should contact their department or the study abroad website for additional information.

Sponsored Programs

The university has designated a few study abroad programs administered by other organizations or universities as sponsored programs. To participate in these programs, students pay a university fee equivalent to current tuition, room and board, and retain their eligibility for all financial aid. Carnegie Mellon in turn pays the program costs to the study abroad program or institution. Where applicable, funds are distributed to the student for room, board, travel, and personal expenses.

Currently, Carnegie Mellon has approximately 50 sponsored programs available around the world. A full list can be found at www.cmu.edu/studyabroad (<http://www.cmu.edu/studyabroad/>) or in consultation with a study abroad advisor.

External Programs

Students may also participate in a program hosted by another university or study abroad organization if the student's home department approves the program and its course offerings. Students will pay the other organization or institution directly. Students who receive institutional aid from Carnegie Mellon will not be eligible for this aid while they are abroad. However, students with state and federal aid will still qualify. Students can learn more about external program options during study abroad advising appointments, information sessions, or on the study abroad website.

Undergraduate Academic Regulations

All enrolled students are required to comply with the university's Academic Regulations, as well as official University Policies (www.cmu.edu/policies (<https://www.cmu.edu/policies/>)). Students are expected to familiarize themselves with these regulations and are also advised to pay special attention to all academic dates and deadlines (www.cmu.edu/hub/calendar (<https://www.cmu.edu/hub/calendar/>)). The university reserves the right to change regulations and policies whenever such action is deemed appropriate or necessary.

Academic regulations are compiled by the University Registrar's Office. Students who have questions regarding these regulations should consult with their academic advisor.

Courses & Registration

Availability of Required Courses

In order to ensure that students do not have to compete for access to their required courses, registration priority is given to students who are registering for courses in their primary major. Although the university encourages the exploration of other disciplines, access to courses outside a student's primary major (including those courses that fulfill requirements for an additional major, minor, etc.) is on a space-available basis and is not guaranteed. Students must meet course pre- and co-requisites when registering, and are subject to course space availability. The university is committed to ensuring that each degree candidate has access to a normal course load before permitting other students to register for a greater than normal number of units.

Change in Schedule (Add/Drop)

Scheduling changes must be made within the period in the semester as established in the Official Academic Calendar (<https://www.cmu.edu/hub/calendar/>). A student **cannot drop a course** by simply notifying the instructor or by ceasing to attend class. A student dropping all of their courses (with the intent of leaving the university) must file an Application for Withdrawal or an Application for Leave of Absence (see the "Student Leave Policy" (p.) for more information).

Students are considered full time if registered for 36 or more units. Students should be sure to confirm their class level and enrollment status in SIO (<https://s3.as.cmu.edu/sio/>) prior to registering. Students must be registered for courses by the tenth day of classes or they will be administratively withdrawn for the semester. Any student who has been administratively withdrawn in error should immediately contact their academic advisor.

Students may drop a course by following the instructions for dropping a course in Student Information Online (SIO) on or before the appropriate deadline as published in the Official Academic Calendar. When a course is dropped by the drop deadline, the course is removed and does not appear on the academic record. Students may also use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean. Undergraduate students will receive three course drop vouchers throughout their undergraduate academic career and master's students will receive one voucher per 12 months of study. Only one drop voucher may be used per semester. In order to drop below 36 units, students must see their advisor for special permission. Vouchers are not intended to be used for exceptional or extenuating circumstances and they cannot be used to drop below full-time status (36 units). International students who wish to drop below full-time must consult the Office of International Education.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition and submit it to the University Registrar's Office. When a course is withdrawn by the course withdrawal deadline, a "W" grade appears on the academic record.

The Late Add form is used for adding a course or switching sections after the add period and during the semester in which the course is offered. Students can check SIO to see if the appropriate schedule changes have been made. Undergraduate students who add a course or switch a section after the add period are required to obtain the permission of their advisor

and home dean's office. Graduate students must have the permission of their department.

View details about course adds, drops and withdrawals on The HUB website (<https://www.cmu.edu/hub/registrar/course-changes/>).

Free Electives

A free elective is any Carnegie Mellon course that a student completes that is not being used to fulfill a college, school, major or minor requirement. A maximum of nine units of physical education and/or student-taught (StuCo) courses may be included in the tally of units required for graduation.

Overloads

The university is committed to insuring that each degree candidate has access to a normal course load before it permits other students to register for a greater than normal number of units. A normal course load has been established by each academic department. Students should check with their academic advisor, department head, or dean's office for the definition of a normal course load. Individual colleges may have overload policies that are more restrictive, therefore students should consult with their advisor when considering an overload. Students may register for an overload up to 12 units with the approval of their academic advisor if they have demonstrated their ability to successfully complete a normal course load. Successful completion of a normal course load is defined as having earned at least a 3.00 (3.50 for students in ECE) cumulative QPA through the preceding semester or at least a 3.00 (3.50 for students in ECE) semester QPA in the current semester (in which case all final grades must be recorded before the student can register for the overloaded class). Overloads greater than 12 units or other exceptions must have the approval of the student's associate dean. First-year and transfer students are limited to a normal course load in their first semester of attendance.

Summer Classes

Per the Associate Deans' Council, undergraduate students are now limited to registering for 24 units in summer sessions without advisor approval. If the student's advisor wishes to approve additional units after consulting with the student, the advisor can increase the student's course load units.

Conduct of Classes

Students are expected to attend all scheduled classes unless the instructor explicitly informs the class that other ways of doing the work are acceptable. The action to be taken in regard to tardiness, absence from class or making up late work is the responsibility of the individual instructor; the instructor should consult with the department head and the student's dean if major action, such as dropping the student from the course, is being considered.

All classes will be held at their scheduled hour on days immediately before and after all holidays and recesses. Both faculty and students are expected to be present.

Members of athletic teams and other student organizations are permitted to be absent from classes to participate in authorized contests and presentations, either at home or out of town, provided the following conditions are met:

- All work missed must be made up to the satisfaction of the instructor concerned;
- No trip shall involve an absence of more than two days, excluding days when classes are not scheduled;
- The total number of days of absence shall not exceed six per sport or per organization annually;
- Each student will obtain an absence authorization signed by the director or sponsor of the organization involved and by the Dean of Student Affairs. The student will present this authorization to the instructor. This is not an excuse for work missed.

Technology affords many students access to mobile devices. It is expected that students will respect the wishes of faculty with regard to the use of electronic devices within the academic environment.

Students who, because of religious beliefs, cannot attend class may arrange as individuals to be absent, provided the work missed is made up in a manner satisfactory to the instructor of the class missed.

No student shall leave a scheduled exercise because of the absence of the instructor until a reasonable time has passed. By tradition and as a matter of courtesy a student should wait 10 minutes before leaving.

Course Attendance, STUDENT ACCOUNT BALANCE and Enrollment

A student is responsible for the payment of charges incurred at the university by the stated payment deadline. The purpose of this policy statement is to detail the specific process and action steps to be used to resolve any outstanding student account balance.

Students will be held financially and academically accountable for courses they attend or for which they are enrolled. Enrollment in a course which is not actively taken, or contrarily, the taking of a course for which enrollment has not been completed, will result in the assignment of a grade and responsibility for applicable tuition charges.

Students who fail to resolve their enrollment and balances will be prohibited from using university academic and administrative services. The services include, but are not limited to, computing facilities, library services, housing, dining, career center services, degree verification and the release of academic transcripts for the upcoming semester.

Undergraduate Course Meetings

Usually, no undergraduate classes, exams, academic, or artistic activities (including extra help sessions, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:40 and 6:40 p.m. On occasion, some courses may be scheduled during these hours by the University Registrar's Office when they also are offered at other times; students may elect to take such courses during the 4:40 to 6:40 p.m. period.

Grades, Transfer Credit, Advanced Placement

Grading Policy

www.cmu.edu/policies/student-and-student-life/grading.html (<https://www.cmu.edu/policies/student-and-student-life/grading.html>)

This policy offers details concerning university grading principles for students taking courses, whether those students are undergraduates, non-degree students or graduate students. This policy covers the specifics of assigning and changing grades (including final and mid-semester grades, incompletes and conditional failures), grading options (audit and pass/fail), drop/withdrawals, and course repeats, as well as defines the undergraduate and graduate grading standards.

Questions about grading for a specific course should be addressed to the instructor of the course in question. Graduate students with questions about pass/fail and drop/withdrawal should contact their individual program. Appeals for an exception to any grading policy may be made by the dean's office of the student's home college.

Definitions

Certain terms are used in this document with specific meanings, as defined in this section.

Student means any full-time or part-time degree-seeking undergraduate or graduate student, or full-time or part-time non-degree student.

Non-degree student means a student who is not in a university degree program.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in their first year), and part-time faculty.

Instructor means a faculty member, teaching assistant, and/or lecturer who is the instructor of record, as recorded in the Student Information System (S3).

Policy Provisions

Assigning Grades

Final grades are awarded to each student, in each course scheduled, at the end of the semester, mini-semester or summer session. All students taking a course at Carnegie Mellon must be assigned grades.

The University Registrar's Office will query instructors who do not assign a grade to a student. Copies of the query regarding the lack of grade will be sent to the course's department head and associate dean. If the instructor does not assign a letter grade or an incomplete grade within one month of that query, the teaching department head will be responsible for insuring that a grade is assigned.

Changing a Grade

A student who believes that an assigned grade is incorrect may request that a final grade be changed. This action should be taken as soon as possible but no later than one year after the final course grade was issued. Final grades will be changed only in exceptional circumstances and only with the approval of the instructor and, for undergraduates, with the approval of the dean's office of the college/school offering the course; for graduate students, department approval is required. The intention of this policy is to ensure that, under normal circumstances, all students in a class are treated equally and no student is unduly advantaged.

Mid-Semester Grades

Mid-semester grades provide valuable feedback to students as they assess their performance in courses. Furthermore, mid-semester grades and the QPAs they generate are used by deans and advisors in identifying and dealing in a timely way with students in academic trouble. Therefore it is imperative that mid-semester grades accurately reflect student performance and are turned in on time.

Mid-semester grades are not permanent and are kept only until final grades are recorded. Because mid-semester grades are not permanent, changes of mid-semester grades as a rule will not be accepted.

Incomplete Grades

Carnegie Mellon students are expected to complete a course during the academic semester in which the course was taken. However, if the instructor agrees, a grade of I (incomplete) may be given when a student, for reasons beyond their control, has been unable to complete the work of a course, but the work completed to date is of passing quality and the grade of incomplete provides no undue advantage to that student over other students.

In awarding an I grade, an instructor must specify the requirements for completing the work and designate a default letter grade where no further work is submitted. Students must complete the required course work no later than the end of the following academic semester, or sooner if required by prior agreement. The instructor must record the permanent grade by the last day of the examination period of that following semester, or the University Registrar's Office will administratively assign the default grade.

Pass/No Pass Grades

Undergraduate students may elect to take a free-elective course pass/no-pass unless precluded by the course, the course's department or the student's home department/college. Policies for graduate students vary and students should be advised to check with their individual colleges/departments/programs for details.

A student must submit a Pass/No-Pass form to the University Registrar's Office indicating the course they are electing as pass/no-pass before the end of the university's withdrawal period. This decision is irreversible thereafter. No information regarding the student's decision will be passed on to the instructor. Instructors will submit letter grades, which will automatically be converted to pass/no-pass.

Work graded A through D will receive credit for units passed and be recorded as P on the student's academic record; below D work will receive no credit and will be recorded as N on the student's academic record. No quality points will be assigned to P or N units; P or N units will not be factored into the student's QPA.

In exceptional circumstances, departments may ask to designate a course pass/no-pass or request that the course be evaluated only with letter grades. The College Council must approve designating a course as pass/no-pass only or as graded only. If such a decision will have an adverse effect on the requirements of any other college, Academic Council must review the decision. The decision to designate a course as graded or pass/no-pass must be made before the add period for the course and is irreversible thereafter.

Audit Grades

Auditing is presence in the classroom without receiving academic credit, a pass/fail or a letter grade. The extent of a student's participation must be arranged and approved by the course instructor. A student wishing to audit

a course is required to register for the course, complete the Course Audit Approval form, obtain permission of the course instructor and their advisor, and return the form to The HUB prior to the last day to add a course.

Any student enrolled full-time (36 units) may audit a course without additional charges. Part-time or non-degree students who choose to audit a course will be assessed tuition at the regular per-unit tuition rate.

Drop/Withdrawal Grades

Students at Carnegie Mellon may drop a course by accessing online registration in SIO on or before the drop deadline as published in the official university calendar. Policies for graduate students vary and students should be advised to check with their individual colleges/departments/programs for details. When a course is dropped by these deadlines, the course is removed and does not appear on the academic record.

Undergraduate students who wish to withdraw from a course after the drop deadline must complete a Course Withdrawal form and **must** obtain their academic advisor's signature. The advisor will indicate whether they "recommend" or do "not recommend" withdrawal from the course on the form, sign the petition, and assign the "W" (withdrawal) grade in S3. The "W" grade will appear on the academic record. Withdrawal grades do not apply to graduate students, except in CFA, DC and SCS. Students may use a late drop voucher for a limited number of course drops after the deadline during the pursuit of their degree. This action must be taken through consultation with their academic advisor or associate dean. Learn more about course drops, withdrawals and vouchers at www.cmu.edu/hub/registrar/course-changes/ (<https://www.cmu.edu/hub/registrar/course-changes/>).

Undergraduates who are registered as full-time students as of the 10th day of classes are expected to remain full-time for the duration of the semester. Full-time is defined as registered for a minimum of 36 units. Permission to drop below the 36-unit minimum can only be granted in extraordinary circumstances by the student's home associate dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Course Repeats

When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade, including pass/fail.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's dean or department head. When a student takes a course they have already passed, only one set of units will count toward graduation requirements.

University Grading Standards

The undergraduate student grading standard is as follows:

| Grade | Quality Points | Definition |
|-------|----------------|---|
| A | 4.0 | Excellent |
| B | 3.0 | Good |
| C | 2.0 | Satisfactory |
| D | 1.0 | Passing |
| R | 0.0 | Failure |
| P | Non-Factorable | Passing |
| N | Non-Factorable | Not Passing |
| O | Non-Factorable | Audit |
| W | Non-Factorable | Withdrawal |
| I | Non-Factorable | Incomplete |
| AD | Non-Factorable | Credit granted for work completed at another institution or examination credit |

This grading standard is for all students classified as seeking an undergraduate degree and special students taking undergraduate courses.

Any +/- grades received by undergraduate students when taking graduate-level courses will automatically convert to the corresponding letter grade as listed in the scale above.

The graduate student grading standard is as follows:

| Grade | Quality Points | Definition |
|-------|----------------|---|
| A+ | 4.33 | (Not applicable to CIT or Dietrich College students) |
| A | 4.0 | |
| A- | 3.67 | |

| | | |
|----|----------------|---|
| B+ | 3.33 | |
| B | 3.00 | |
| B- | 2.67 | |
| C+ | 2.33 | |
| C | 2.00 | |
| C- | 1.67 | |
| D+ | 1.33 | (Not applicable to Tepper School, Heinz College, or Dietrich College students) |
| D | 1.00 | (Not applicable to Tepper School, Heinz College, or Dietrich College students) |
| R | 0.0 | Failure |
| S | Non-Factorable | Satisfactory |
| P | Non-Factorable | Passing |
| N | Non-Factorable | Not Passing |
| O | Non-Factorable | Audit |
| W | Non-Factorable | Withdrawal |
| I | Non-Factorable | Incomplete |
| AD | Non-Factorable | Credit granted for work completed at another institution or examination credit |

Grading standards are based upon a student's home academic program and is defined by their home college. The college's standards determine if certain grades are applicable and if undergraduate courses are factored into their mid-semester and final semester quality point averages (QPA). Otherwise, the university policy is that only graduate courses (600 level and higher) are factored into the semester QPA.

Pass/fail policies for graduate students vary and students should be advised to check with their individual college/department/program for details.

Minimum passing grades in graduate courses are determined by the department and college policy. Any course that a graduate student completes will be graded using the scale above. This includes undergraduate courses taken by graduate students, and non-degree students taking graduate courses.

Contact

Questions concerning this policy or its intent should be directed to the University Registrar's Office at 412-268-7404.

Units and Quality Points

Carnegie Mellon has adopted the method of assigning a number of "units" for each course to represent the quantity of work required of students. For the average student, one unit represents one work-hour of time per week throughout the semester. The number of units in each course is fixed by the faculty member in consultation with the college offering the course. Three units are the equivalent of one traditional semester credit hour.

Hence, a 9-unit semester-long course should require 9 hours of student engagement, on average, including class time; if the instructor requires 3 hours of lecture and 1 hour of recitation, they can expect students to spend 5 hours outside of class engaging in class work. For mini courses that run for only seven weeks, the conversion from units to number of hours per week during the mini involves multiplying by 2. For example, a 6 unit mini course should on average involve 12 hours of student engagement; if the instructor requires 3 hours of lecture and 3 hours of lab, they can expect the students to spend 6 hours outside of class.

Final grades are given "Quality Point Values" as follows:

| Grade | Meaning | Quality Point Value |
|-------|----------------|---------------------|
| A | Excellent | 4 |
| B | Good | 3 |
| C | (Satisfactory) | 2 |
| D | Passing | 1 |
| R | Failure | 0 |

Units earned for a course multiplied by the Quality Point Value of the grade given for that course equals the quality points for that course. For example, a 9-unit course assigned a "C" grade is awarded 18 quality points (9 units x 2 quality points = 18 quality points). Total Quality Points divided by Total Units Factorable equals the Quality Point Average.

For example, a student's record in one semester might be:

| | |
|--|--------------------------|
| 11 units x 4 quality points = | 44 quality points |
| 10 units in Physics "R" | |
| 10 units x 0 quality points = | 0 quality points |
| 9 units in Chemistry "B" | |
| 9 units x 3 quality points = | 27 quality points |
| 9 units in History "C" | |
| 9 units x 2 quality points = | 18 quality points |
| 9 units in English "D" | |
| 9 units x 1 quality point = | 9 quality points |
| Total Units = 48 | |
| Total Quality Points = 98 | |
| Quality Point Average (98 divided by 48) = 2.04 | |

"I" (incomplete), "P" (pass), and "W" (withdrawal) grades are not awarded quality points and are not considered "factorable" units when calculating the QPA.

The same procedure is applied to all grades earned at the university to establish the Cumulative Quality Point Average.

Dean's List

Undergraduate students who meet specific academic requirements are added to their home college's Dean's List each semester. This is noted on the student's transcript for applicable semesters. Each college may have its own requirements for Dean's List qualification; these are described in the individual college sections of the catalog. Note: Only undergraduate *degree-seeking* students may earn a place on the Dean's List. Non-degree students are not eligible.

Transfer Credit Evaluation and Assignment Policy

The Policy on Grades for Transfer Courses, originally dated January 13, 1993, and approved by the Committee on Educational Programs and Student and Faculty Affairs states:

"Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon University transcript will include information on such courses as follows:

Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA. All other courses will be recorded on this transcript indicating where the course was taken, but without grade. Such courses will not be taken into account for academic actions, honors or QPA calculations. Note: Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this.

Definitions

A Carnegie Mellon course is one conducted under Carnegie Mellon University regulations regarding course content and grading and taught by faculty under the supervision of a Carnegie Mellon academic unit. Courses taught by Carnegie Mellon faculty on the Carnegie Mellon campus qualify. Courses that are part of the regular offerings of other universities do not qualify, unless faculty at the other universities receive appointments at Carnegie Mellon and handle Carnegie Mellon students under Carnegie Mellon academic regulations.

Courses offered for cross-registration are those taken under the PCHE (Pittsburgh Council on Higher Education) agreement during the regular academic year."

Only official and final college or university transcripts will be accepted for the awarding of transfer credit. Grade reports, letters and the like are not acceptable. It is the responsibility of the Office of Undergraduate Admission and the University Registrar's Office to verify official transcripts. Official transcripts for the awarding of transfer credit will reside in the student's permanent university academic folder in the University Registrar's Office.

It is the responsibility of each academic department to review and establish transfer course credit for their degree-seeking students.

Transfer Credit Evaluation Procedure

External Transfer Students

External applicants applying for transfer to Carnegie Mellon will arrange for submission of:

- official transcripts to the Office of Undergraduate Admission as part of the admission process.
- official, final transcripts to the Office of Undergraduate Admission once they are admitted and prior to their beginning coursework at Carnegie Mellon.

As part of the admission process, the Office of Undergraduate Admission will verify the official final transcripts, and then send them to the appropriate academic unit responsible for college/department acceptance decisions. Each unit will be responsible for the review of transfer credit and the establishment of transfer course credit for each individual student.

Current Students

Current Carnegie Mellon students taking courses at other accredited institutions (colleges and universities), during either summer semesters or as part of exchange programs or other departmentally approved programs, or while on leave from Carnegie Mellon, must arrange for the submission of official final transcripts to the University Registrar's Office.

Upon receipt, the University Registrar's Office will verify these official transcripts and send a copy of the transcript to the appropriate academic unit responsible for that student's college/department transfer credit decisions. The official transcript will reside in the student's university academic record in the University Registrar's Office. Each unit will be responsible for its students' transfer credit review and the establishment of transfer course credit for each individual student. Should a unit receive the official transcript, it must be sent immediately to the University Registrar's Office.

Standard Course Equivalents for Advanced Placement/International Baccalaureate Units Policy

The university has standard units assigned to Advanced Placement (AP) and International Baccalaureate (IB) credits for all majors. Standard course equivalencies for each exam will be determined by "expert departments" in each college for each acceptable AP/IB score.

Under this procedure, students' AP or IB credit for a particular course will only go toward their degree requirements if allowed by the home department or college policies. Should a student decide to transfer to another major and/or academic unit within the university, AP/IB credit applicability to new degree requirements will depend upon the requirements of the new home department (or college). Students may only be granted credit for the Higher Level IB exams. This policy assumes no significant AP and/or IB exam changes. In the event of significant exam changes, students will be notified of any resulting policy changes no later than July 30 prior to their enrollment to take effect the fall of that year.

Credit is also given for Cambridge International/EdExcel Advanced Level courses. Learn more about AP, IB and Cambridge credits at www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html (<https://www.cmu.edu/hub/registrar/registration/ap-transfer-credit.html>).

Rank in Class

Undergraduates at Carnegie Mellon pursue degrees in one or more of our ten schools or colleges. They may choose to pursue coursework, majors and minors within and between schools/colleges. In an institution where students' educational experiences are so varied, class rank is not a meaningful way to measure achievement.

Carnegie Mellon does not report nor record students' rank in class, rank in college and rank in department. Graduate school and/or employment requests that ask for a students' rank will be completed with the statement "Carnegie Mellon does not report rank in class."

Transcripts & Verifications

Transcripts

The student's official transcript is to be considered the official record for all degree(s), major(s), minor(s), and honors. The official Carnegie Mellon transcript includes both the undergraduate and/or graduate record(s). All transcripts come in individually sealed envelopes, unless otherwise specified. Transcript requests are not processed if the student has an outstanding obligation, financial or otherwise. We cannot accept phone

or email requests and we are not able to fax a transcript under any circumstances.

Visit www.cmu.edu/hub/registrar/student-records (<https://www.cmu.edu/hub/registrar/student-records/>) for complete information, including how to order a transcript.

Verifications

Enrollment and degree verifications are available for currently enrolled Carnegie Mellon students and Carnegie Mellon Alumni. A verification officially confirms information about you. Please note that we cannot fax your QPA or verifications that contain anything besides the following:

- Name
- Local address
- Local phone number
- Email address
- Class
- College
- Department
- Dates of attendance
- Date(s) of graduation
- Degree(s) awarded

The most common reasons for requesting a verification are:

- Student loan agencies and insurance companies asking if a student is enrolled.
- Scholarship committees asking if a student maintained a certain QPA.
- Potential employers asking if a student graduated with a certain degree.

Online Verification Ordering

Currently enrolled Carnegie Mellon students may order enrollment verifications via Student Information Online (SIO) (<https://s3.as.cmu.edu/sio/>). Additional information can be found at www.cmu.edu/hub/registrar/student-records (<https://www.cmu.edu/hub/registrar/student-records/>).

Full-Time Status

Undergraduates who are registered as full-time students as of the end of the course add period (typically, the 10th regularly scheduled class day) are expected to remain full-time for the duration of the semester. Full-time is defined by a minimum of 36 units. Permission to drop below the 36 unit minimum must be granted by the student's associate dean. Undergraduates who are registered as part-time are also subject to the above deadlines to drop or withdraw from a course.

Students carrying a full-time course load at the end of the course add period (typically, the 10th regularly scheduled class day) are not ordinarily permitted to drop below 36 units after that time. Exceptions must be authorized by the student's associate dean.

Status, Class Standing

Students should refer to the sections of the catalog pertaining to their college and/or department to determine the number of units required each academic year by their specific curriculum. Students must achieve passing grades in order to earn units; students do not earn units for incomplete or failed courses.

A first-year student becomes a second-year student after earning passing grades in three-fourths of the units required by their first-year curriculum.

A second-year student becomes a third-year student after earning the number of units required by their first-year curriculum plus three-fourths of the number of units for the second year.

A third-year student becomes a fourth-year student after earning the number of units required by their first-year and second-year curriculum plus three-fourths of the number of units for the third-year.

Classification of students is made only at the time of their first registration in any academic year and remains unchanged throughout the rest of that academic year.

Course Description Requests (for prior years)

Please note that University Archives does not have access to transcript and verification information. They maintain only the course description archives.

If you call or email this office, your request will not be processed. Please contact:

Archives/Art Inventory Specialist
Carnegie Mellon University Libraries
4909 Frew St.
Pittsburgh, PA 15213
412-268-5021 (phone)
412-268-7148 (fax)

Graduation & Diplomas

Degree Requirements

Students are responsible for checking to ensure that the degree requirements (as listed in the appropriate catalog at the time of their matriculation) have been met. They may also refer to the Stellic (<https://academicaudit.andrew.cmu.edu/>) online degree audit application. If the degree requirements have been modified by College Council action, the student is responsible for checking to ensure that the modified requirements have been met.

To be eligible to graduate, undergraduate students must complete all residence and course requirements for their program with a cumulative Quality Point Average of at least 2.0. For undergraduate students who enrolled at Carnegie Mellon as a first-year and whose first-year grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the first year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including their first year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

No student may receive a diploma until all financial obligations to the university have been met.

Residency Requirement

A candidate for the bachelor's degree must complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Note that these are minimum residency requirements applicable to all university undergraduates. Some of the university's colleges and departments have developed more restrictive requirements in this area. Students should consult that section of the catalog in which their college or department's academic regulations are presented for the residency requirements applicable to them. Deviation from these policies requires action by the dean of the student's home college.

Implications of Residency Requirements for transfer students seeking a second undergraduate degree: Students who received degrees from other universities could have up to 2 years of credits earned elsewhere applied to their Carnegie Mellon degree requirements and would need to meet Carnegie Mellon's Residency Requirement and complete at the university a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework. Deviation from these policies will require action by the dean of the student's home college.

Diplomas

A Carnegie Mellon diploma is a student's certificate of accomplishment. The diploma is printed with the name the student approved within Student Information Online (SIO), along with the student's primary degree and major (i.e., Bachelor of Arts in Creative Writing), and if applicable, additional major(s). Minors are not listed on a diploma, although they do appear on an official transcript.

Diplomas are distributed to graduates during or immediately following the May Commencement Ceremony. Certain circumstances will result in students receiving their diplomas at a later date; these students will be informed of this well before the ceremony. If a student is unable to attend the ceremony, diplomas will be mailed in the weeks following commencement. Diplomas are not available prior to the stated date of graduation. August and December graduates will receive their diploma via the mail.

The diploma is 14x17 inches and is marked with a multi-colored and gold seal.

Graduation with University Honors

In recognition of exemplary academic achievement as undergraduates, some candidates for undergraduate degrees will be named to the University Honors List. Each of the undergraduate colleges will select students for honors on the basis of a cumulative grade point average (typically when cumulative QPA is greater than 3.5) and/or recommendation of the faculty.

Standard Degree Terminology

Carnegie Mellon University offers a wide variety of programs; the opportunities vary greatly between and among the colleges. For the purposes of clarification, this section defines:

- standard degree terminology;
- changes to the existing degree declaration process;
- the existing procedure for creating new degrees, majors and minors.

Degree

Examples: B.S. (Bachelor of Science); M.F.A. (Master of Fine Arts); Ph.D. (Doctor of Philosophy)

Major

Field studied in greatest depth by fulfilling a department-determined set of course requirements. The primary major is the field in which the degree is granted.

Example: Creative Writing; Physics; Marketing

Students may pursue an additional major(s) in a single degree program.

Minor

Field(s) studied for educational enrichment by fulfilling a department-determined set of course requirements. Graduate students may not pursue minors. Minors are not listed on the diploma but appear on the student's transcript. The type of degree sought is determined by the major (that of the home department), not the minor. Examples: Film Studies; Game Design

Option

(Now referred to variously as track, option, etc.)

A specific area of study associated with the major or an additional major(s), which transforms the title of the major or additional major.

Examples: Civil Engineering (Biomedical Engineering Option) Physics (Computer Science Option)

Concentration

(Now referred to variously as track, option, etc.)

A specific area of study generally associated with a major or additional major, which appears only on the transcript.

Home College

The college into which the student was originally admitted or into which the student formally transferred.

Home Department

The department into which the student was originally admitted or the department offering the major which the student has declared.

Concurrent College/Department

College/department other than the home college/department, granting the second of multiple degrees, or offering the additional major(s) of the double or triple major, or minor.

Single Degree/Major

One diploma, stating the degree and the major field of study. Currently, the Statute of Limitations on earning an undergraduate degree is eight years.

Examples: B.A. in Psychology; M.S. in Chemistry.

Requirements: Fulfillment of all requirements of the home college.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: Home college, home department.

Major-Declaration Process

For undergraduates, depending on the student's college, the major is usually declared at the end of the first year or sophomore year.

Departments enter the appropriate majors upon declaration.

For graduate students, the major is usually indicative of the department and is supplied by the department.

Joint Degree

Degree program offered between two or more colleges or departments.

Examples: B.H.A from the College of Fine Arts and the Dietrich College of Humanities and Social Sciences; M.S. in Colloids, Polymers, and Surfaces (Chemistry and Chemical Engineering).

Multiple Degrees

More than one degree granted by the university (whether simultaneous or sequential). The student receives one diploma for each degree. When awarded simultaneously, two degrees are referred to as dual degrees, three degrees as triple degrees. Multiple graduate degrees may be given in conjunction with an outside university.

Examples of how such degrees appear on the respective diplomas:

- Bachelor of Fine Arts in the field of Art; Bachelor of Science in the field of History
- Bachelor of Science in the field of Physics; Bachelor of Science in the field of Computer Science

Requirements: Multiple bachelor's degrees

Declaration: Undergraduates must declare at least by registration time (early November), during the first semester of the junior year.

To receive multiple bachelor's degrees the student must:

- satisfy all requirements for each degree.
- complete an aggregate number of units that exceeds, by at least 90, the minimum unit requirement for the degree with the smallest such requirement (i.e., if one of the degrees requires a minimum of 360 units and the other requires 380 units, a total of at least 450 units (90 plus 360, the smallest of the two) is required to obtain both degrees).
- comply, for each degree, with the statute of limitations regarding the time at which units are earned.
- while working towards more than one degree simultaneously, designate one of the departments (and if necessary colleges) as the home college/department.

Additional Major

One degree, stating the major in the home department first and the additional major second. The type of degree given (B.A., B.S.) is determined by the major of the home department.

For example, a student whose home department is Physics:

This degree is valid: B.S. in Physics with an additional major in History

This degree is not valid: B.S. in History with an additional major in Physics

The intent of a double major is an in-depth understanding of two major fields. Students may pursue a second major in a field where the primary degree is different from the degree associated with the additional major: i.e., B.S. in Economics with an additional major in History.

Requirements: If the double majors involve two different colleges OR the same college, the student must fulfill:

- all requirements (including core) for the first major degree as defined by the home college;
- all major requirements (including core prerequisites) for the additional major;
- any specific requirements for double majors imposed by the department(s)/college(s) involved.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: Home college, home department; concurrent college (if any), concurrent department (if any).

Additional Majors

One degree, stating the major of the home departments first, the second and the third major afterwards. The type of degree sought (B.A., B.S.) is determined by the major in the home department.

For example, for a History student, this degree is valid: B.A. in History with additional majors in Professional Writing and in Hispanic Studies. This degree is not valid: B.A. in Professional Writing with additional majors in History and in Hispanic Studies.

Requirements: If the triple major involves two or three different colleges OR the same college, the student must fulfill all requirements listed for each additional major.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: department

Concurrent college (if any), concurrent department (if any)

Second concurrent college (if any), second concurrent department (if any)

Minor

One degree, stating the major first and the minor second (or third, if there is also (an) additional major(s) involved). The type of degree sought (B.A., B.S.) is determined by the major (that of the home department). Minors are not listed on the diploma, but appear on the transcript.

Examples: B.F.A. in Music Performance (Voice) with a minor in Theatre Arts; B.S. in Applied History with an additional major in Information Systems and a minor in Mathematics.

Requirements: The student would generally take 45 units pertaining to the minor, in addition to fulfilling all requirements for the major degree (as defined by the home college). The "minor" courses are negotiated between the student and the department certifying the minor.

Declaration: At least by registration time (early November), during the first semester of the junior year.

Certification: department

Concentrations (Tracks, Options, Specializations, Area Cores, etc.)

These concentrations will not be considered part of the student's degree title unless the concentration is included as part of the major or (an) additional major(s) field title.

Additional Majors/Minors Declaration Process

For undergraduates, all variations on a student's intended degree and major field must be declared by the end of the first semester of the student's junior year. Having already declared a major, students should be well prepared by this time to choose additional majors and/or minors.

It is assumed that by these proposed deadlines, the student will have taken a majority of degree requirements and electives. The student can then, in conjunction with an advisor, review their course history and decide which options may or may not apply towards a supplemental degree and field(s), and then receive a detailed curriculum for attaining the additional desired degree, major or minor. The student should then notify the college/department offering the additional program. Upon receipt of this notification, the college/department will update the Student Information System which will allow this information to be reflected in the Commencement System for graduation. This procedure ensures that when a student is expected to graduate, all degree/major information is immediately accessible, and certification of the degree is simplified.

Multiple Degrees Involving Graduate Degrees

Policies involving multiple graduate degrees or a graduate/undergraduate degree program or sequence are dictated by each college involved.

Examples: M.S. in Public Management and Policy and the degree of Juris Doctor (Heinz College/University of Pittsburgh School of Law).

Declaration: Undergraduates: at least by registration time (early November), first semester junior year.

Declaration: Graduates: upon admittance OR by the end of the semester preceding the expected graduation date.

Certification: Home college, home department and concurrent college (if any), concurrent department (if any).

Degree Certification

undergraduate PROGRAM STANDARD DEGREE REQUIREMENTS & DEGREE CERTIFICATION

Carnegie Mellon undergraduate students are expected to complete their program of study within eight semesters of full-time enrollment, or 10 semesters for undergraduate students in the Bachelor of Architecture (B.Arch.) program. The standard undergraduate program of study is grounded in a primary degree and its requirements, and may be complemented by an additional major(s) or minor(s) as part of the student's academic plan or as a requirement of the primary major. Upon completion

of all primary degree requirements within the program of study in the standard number of eight semesters (or 10 for B.Arch.), the degree will be certified by the student's academic program in the semester in which the student completes the requirements.

Early Completion

Students who complete their primary degree requirements within their program of study in fewer than eight semesters (or 10 for B.Arch.) may have their degree certified upon the completion of all requirements in consultation with their academic advisor(s).

Longer-than-Standard Completion

Longer-than-standard degree completion may occur due to academic interruptions in making progress toward the degree as defined by the academic program and/or the Student Financial Aid Satisfactory Academic Progress policy, interruptions of full-time study or progress toward the degree due to serious, documented medical issues, or other unusual or unforeseen circumstances. Students who complete their primary degree requirements within their program of study in more than the standard number of semesters will be certified in the semester in which they have completed their primary degree requirements, pursuant to close and regular consultation with their academic advisor(s).

Additional Guidance for Students

Program of study. Students seeking guidance about their program of study and degree requirements should consult with their academic advisor and/or appropriate associate dean.

Financial aid and student account. Students are expected to make normal progress toward their degree in order to graduate within the standard timeframe for their program of study. Under U.S. Federal Title IV regulations, student eligibility for federal financial aid is contingent upon enrollment in and successful completion of courses that are counted as credit toward their current degree program. To receive the maximum amount of federal and state financial aid for which they may be eligible, students must enroll each semester in at least 36 units that count toward their current degree level. CMU institutional undergraduate grants support undergraduate degree completion and on-time graduation; institutional undergraduate grants for students in undergraduate programs and in integrated undergraduate and master's degree programs are renewable for eight semesters (and 10 for B.Arch.). (See separate guidance regarding integrated bachelor-master's degree programs.)

Students should consult with their designated college liaison in The HUB regarding billing and financial aid, particularly for early completion, longer-than-standard completion, or integrated undergraduate and master's degree programs.

International students. Immigration status for students in F-1 and J-1 non-immigrant status is tied to making normal progress toward completing degree requirements. Therefore, F-1 and J-1 students who are considering completing their degree requirements early, anticipating longer-than-standard completion, or moving from an undergraduate to a graduate student classification (integrated undergraduate-graduate study), should consult with their designated advisor in the Office of International Education (OIE) to ensure compliance with immigration regulations.

Guidance for Academic Advisors and Deans

Advisors and associate deans may direct questions regarding degree certification, norms or exceptions to the University Registrar or to the Vice Provost of Education.

Integrated Bachelor & Master's Degree Programs STANDARD DEGREE REQUIREMENTS & DEGREE CERTIFICATION

The integration of bachelor and master's degree programs ("IBM" programs) benefits CMU students who elect to maximize their use of time and academic energy to blend their undergraduate studies with master's-level study in close combination, in an integrated program of study at CMU. Some CMU departments and programs have developed integrated options for students in response to student desires for such opportunities and to enliven their graduate programs with students who are well-acclimated to the rigor and demands of the CMU educational experience.

General Information

Carnegie Mellon students in integrated bachelor-master's programs are expected to complete their degree requirements within a standard length of time for their full-time program of study as outlined in the Undergraduate Catalog and relevant Graduate Student Handbook. This document describes several standard models for the CMU integrated bachelor-master's degree

programs, some of which involve acceleration of either the undergraduate or the graduate degree component (or both) within the integrated program designs. Each CMU integrated program offers specific, pre-determined model(s) of integrated study reflecting one of the following:

- 4+0 meaning that a student will complete both undergraduate and master's degree coursework in eight semesters (four years) of full-time study. This model generally applies when the undergraduate and graduate field of study are the same, such as an undergraduate and master's degree in Chemistry or Mathematics.
- 3-1-1 meaning three years of full-time undergraduate coursework, followed by one year of integrated undergraduate and graduate study, and one year of exclusively master's level coursework for a total of five years of full-time study. An example would be undergraduate degrees integrated with Heinz College or Tepper graduate degree programs. The undergraduate degree generally is completed in eight semesters of full-time study (or less.)
- 4+1 semester meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by one semester of exclusively master's level coursework for a total of four and a half years. The undergraduate degree generally is completed in eight semesters of full-time study (or less.)
- 4+2 semesters meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by two semesters of exclusively master's level coursework for a total of five academic years. The undergraduate degree is completed in eight semesters of full-time study (or less.)
- 4+3 semesters meaning eight semesters (four years) of full-time undergraduate coursework including integration of some master's level courses, followed by three semesters of exclusively master's level coursework for a total of five and a half academic years. The undergraduate degree is completed in eight semesters of full-time study.
- 5+1 for architecture meaning five years of Bachelor of Architecture (B.Arch.) undergraduate coursework followed by two semesters of full-time master's level coursework for a total of six academic years. The B.Arch. undergraduate degree generally is completed in 10 semesters.

The standard undergraduate program of study is grounded in a primary degree and its requirements, and may be complemented by an additional major(s) or minor(s) as part of the academic plan. Some students decide to apply for one of CMU's several integrated degree programs to complement their undergraduate degree with an integrated or accelerated master's degree. Depending on the model of the integrated program, when an undergraduate student applies to an IBM program, they recognize that the standard for undergraduate study will be eight semesters (or 10 for B.Arch.), plus one, two, three or four additional semesters of full-time graduate-level study (except for the 4+0 model, above) to complete the master's degree.

CMU students in most IBM programs are considered to be undergraduates until they have completed the requirements for their bachelor degree at which point they are certified by their undergraduate academic program; this typically occurs at the time determined to be the standard for their integrated program following a successful seven or eight semesters (or 10 for B.Arch.) of full-time enrollment, depending on the design of their integrated program. However, in one rare model, the integrated program design holds the bachelor degree certification to be given concurrently with the master's degree in the ninth or tenth semester of full time enrollment.

Early Completion of Undergraduate Degree

An IBM student who has completed all undergraduate degree requirements in fewer than the standard number of semesters for their program may request an early undergraduate degree certification from their undergraduate program, in close consultation with their academic advisor(s). This situation, while possible, is not common due to the necessity of staying on track for both undergraduate and master's degree programs in an integrated manner.

Movement from Undergraduate to Graduate Student Classification

Students in an IBM program who are certified as having completed their undergraduate degree – typically in the number of semesters that is the standard for their integrated program – then will be classified as a graduate student at CMU, and are expected to complete their graduate degree requirements within the standard length of time for their integrated program of study. Students should be aware of and plan for financial implications, including financial aid, and/or F-1/J-1 non-immigrant implications due to the change of level when moving from undergraduate student status to graduate student status at CMU. (See details below.)

Standard for Graduate Component of IBM Student/Program

Upon completion of the graduate program degree requirements in the standard period of study, the graduate degree will be certified in the semester in which the student completes the requirements by the student's graduate program.

Early Completion of Graduate Degree Requirements

Early completion of the graduate degree requirements. Graduate students who consider the completion of all degree requirements in less than the standard length of time for their program of study must consult with their degree-granting program or department to determine if early degree certification is allowed academically and under what circumstances.

Incomplete Graduate Degree Requirements

In some cases, students in an IBM program may withdraw from the graduate component of the program of study and, therefore, will not be certified or awarded the graduate degree. Any such withdrawal decision also may require close consultation with the undergraduate advisor to determine eligibility for undergraduate degree completion and certification if the undergraduate degree is not already certified.

Extended or Longer-than-Standard Graduate Degree Completion

Longer-than-standard degree completion may occur due to academic interruptions in making progress toward the degree as defined by the academic program, interruptions of full-time study or progress toward the degree due to serious, documented medical issues, or other unusual or unforeseen circumstances.

IBM students who require longer than the standard time to complete their graduate degree requirements are expected to remain in close contact with their graduate program, and will be certified at the end of the semester in which they have completed their degree requirements. Students shall reference the CMU Policy on Master's Student Statute of Limitations (<https://www.cmu.edu/policies/student-and-student-life/masters-students-statute-of-limitations.html>) regarding guidelines and restrictions which place an upper limit on the maximum length of time allowable for master's degree completion and certification.

Additional Guidance for Students

Program of study. Students seeking guidance about their program of study and degree requirements should consult with their academic advisor and/or appropriate associate dean.

Financial aid and student account. Students are expected to make normal progress toward their degree in order to graduate within the standard timeframe for their program of study. Under U.S. Federal Title IV regulations, student eligibility for federal financial aid is contingent upon enrollment in and successful completion of courses that are counted as credit toward their current degree program. To receive the maximum amount of federal and state financial aid for which they may be eligible, students must enroll each semester in at least 36 units that count toward their current degree level. CMU institutional undergraduate grants support undergraduate degree completion and on-time graduation; institutional undergraduate grants for students in undergraduate programs and in IBM programs are renewable for eight semesters (and 10 for B.Arch.).

Students should consult with their designated college liaison in The HUB regarding billing and financial aid, particularly for early completion, longer-than-standard completion, or integrated bachelor and master's degree programs.

International students. Immigration status for students in F-1 and J-1 non-immigrant status is tied to making normal progress toward completing degree requirements. Therefore, F-1 and J-1 students who are considering completing their degree requirements early, anticipating longer-than-standard completion, or moving from an undergraduate to a graduate student classification (integrated undergraduate-graduate study), should consult with their designated advisor in the Office of International Education (OIE) to ensure compliance with immigration regulations.

Guidance for Academic Advisors and Deans

Advisors and associate deans may direct questions regarding degree certification, norms or exceptions to the University Registrar or to the Vice Provost of Education.

Academic Actions

Each college may have its own regulations and procedures regarding academic actions, but in general, the following apply to all undergraduate students.

Student Suspension/Required Withdrawal Policy

Policy Statement

University Suspension is a forced, temporary leave from the university. There are three types of suspension for students that apply to both graduate and undergraduate students:

- **Academic Suspension** is the result of poor academic performance or violation of academic regulations and is imposed by the student's college or academic department (see university and college academic policies).
- **Disciplinary Suspension** is the result of serious personal misconduct and is imposed by the Office of Student Affairs (see The Word/Student Handbook (<https://www.cmu.edu/student-affairs/theword/>)).
- **Administrative Suspension** is the result of failure to meet university financial obligations or failure to comply with federal, state or local health regulations and is imposed by Student Financial Services (see Student Financial Obligation Terms (<https://www.cmu.edu/sfs/billing/sfo.html>)).

Suspended students may not:

- register for courses
- attend classes
- live in residence halls or Greek housing
- use campus facilities, including athletic facilities, libraries and computer clusters
- participate in student activities
- be members of student organizations
- have student jobs*

*Students on academic suspension may have a summer campus job if they accepted the job before they were suspended.

Employment

Although suspended students may not hold student jobs, students on academic suspension may, under certain circumstances, have a non-student job with the university; students on disciplinary or administrative suspension may not.

To have a non-student job, students on academic suspension must receive approval from their associate dean (undergraduate students) or department head (graduate students) to ensure that the job will not violate their suspension terms. Students in violation of this will lose their degree student status, meaning they would have to reapply for admission to Carnegie Mellon through either the Office of Undergraduate Admission or the appropriate graduate department.

Transfer Credit

Suspended students may take courses elsewhere; however, they may receive transfer credit only if their college's and department's policies allow this.

Appeals

To appeal any action of this policy, the student may write to the following individuals:

- Academic Suspension: Associate dean (undergraduate students) or department head (graduate students)
- Disciplinary Suspension: Dean of Student Affairs
- Administrative Suspension: Vice Provost for Enrollment Management and the Dean of Student Affairs, in consultation with the student's associate dean

Returning from Suspension

In order to return from a suspension, a student must have the following approval:

- Academic Suspension: Associate dean (undergraduate students) or department head (graduate students)
- Disciplinary Suspension: Dean of Student Affairs
- Administrative Suspension: Vice Provost for Enrollment Management and the Dean of Student Affairs, in consultation with the student's associate dean

Procedure for the Appeal of Grades & Academic Actions

In the event a student believes an assigned grade or an imposed academic action is incorrect or not appropriate, the student may follow the processes outlined below to seek a prompt and equitable resolution of the matter.

If a student believes a grade has been incorrectly assigned, the student should:

1. Present the case to the faculty member responsible for the course, providing all supporting data concerning the nature of the discrepancy.
2. If, after a decision is rendered, the student believes that their concerns have not been adequately resolved, the student may pursue a formal appeal with the department responsible for the course. To appeal to the department, a student must present a written statement detailing the grounds for the appeal with appropriate documentation to the head of the department responsible for the course. This appeal must be submitted within seven (7) days of receipt of the faculty member's decision. The department head will provide a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.
3. If the student is not satisfied with the department head's resolution, the student may pursue the appeal at the college level. To appeal at the college level, the student must present copies of all documents originally sent to the faculty member and department head, along with a formal letter of appeal, to the dean of the college responsible for the course. This appeal must be submitted within seven (7) days of receipt of the department head's decision. The dean, or the dean's designate, will review the appeal and will render a written decision, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

If a student believes an academic action is inconsistent with the policies of the college or merits additional review, a student should:

1. Submit a formal written appeal, as specified in the initial academic action, to the associate dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate their case and support their concerns.
2. The dean of the college, or the dean's designate, will review the appeal and issue a decision and the basis for it within thirty (30) days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all previously submitted documents and a formal letter of appeal to the Provost. The Provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical.

Other Academic Regulations

English Fluency for Non-Native English Speakers

To be successful at Carnegie Mellon University, students who are nonnative speakers of English need to begin their undergraduate work with a strong foundation in academic English and a high level of proficiency with speaking, listening, reading and writing in English. The importance of English language abilities cannot be overstated since there are no basic English as a Second Language (ESL) courses at Carnegie Mellon. All students will have sufficient English language proficiency to be able to participate fully in the academic work and to interact in daily life outside of the classroom.

Students' English proficiency will enable them to handle the demands of academic work, including the ability to comprehend, process, and master complex material presented in English, both in written and spoken form. Students will be able to communicate their ideas and questions to faculty, classmates, and others, in a classroom environment that is often highly participatory. For example, many classes require group discussion, team projects, oral presentations, and/or independent research. In addition to proficient English skills, studying in a new culture requires openness and flexibility to adapt to a new, and often very different, academic system.

To assess the language of non-native English speaking applicants, a minimum TOEFL score of 600 (paper based, PBT), or 100 (internet based, iBT) has been established as the standard for admission. This minimum score indicates that an applicant has the fundamental building blocks of language needed for academic tasks and for continued language development. Since neither the PBT or iBT versions of TOEFL assess speaking, students who take these tests should additionally seek feedback

on their speaking skills and work to improve conversational skills before beginning academic work.

Exchange Students

Each term, Carnegie Mellon welcomes exchange students from partner institutions around the world. Exchange students enrich the learning experience at Carnegie Mellon and are expected to be full participants in the curricular and meta-curricular life. Therefore, their admission should adhere to the English language guidelines described above. Exchange students submit standardized English language testing scores (such as the TOEFL) as part of the Exchange application process, and present the same high level of English language abilities as degree-seeking students. With exchange students, high-level English abilities are particularly critical since academic, personal and extracurricular experiences must be maximized in a short period of time, sometimes only four months in duration.

Withdrawal of a Degree

The university reserves the right to withdraw a degree even though it has been granted should there be discovery that the work upon which it was based or the academic records in support of it had been falsified. In such a case the degree will be withdrawn promptly upon discovery of the falsification.

Information for Graduating Students

Graduating students may wear one stole ONLY with their academic regalia. Students are certainly permitted to receive/purchase more than one stole if they are a member of multiple organizations that issue stoles and may choose to wear a particular stole to the main commencement ceremony and another to their diploma ceremony.

Graduating students who are a member of a club/organization that issues a pin to designate affiliation are permitted to wear more than one pin with the academic regalia in addition to one stole.

Retention of Student Work

The university reserves the right in all colleges to retain indefinitely any student work the faculty may select. All work not retained by the university must be claimed at the time specified on the bulletin boards (or other forms of communication) of the department concerned; otherwise, the work will be destroyed.

Degree Statute of Limitations

www.cmu.edu/policies/student-and-student-life/ug-statute-of-limitations-student.html (<https://www.cmu.edu/policies/student-and-student-life/ug-statute-of-limitations-student.html>)

All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight years of the date on which the degree is granted. This statutory period can be extended by the Dean of the student's college under the following conditions:

- the courses taken prior to the statutory period still represent a reasonable part of the student's total academic program;
- the prior courses provide adequate preparation for courses which must still be taken to fulfill the degree requirements;
- there is a legitimate reason(s) for the student not completing the academic program within the statutory period.

A request for a waiver of the statute of limitations must be submitted to the dean of the student's college. The request for a waiver should address all of the above conditions for an extension. For cases in which a waiver is granted, the waiver covers specific courses and is intended for a specific period during which the program must be completed.

Transitional Student Status

Transitional student status has been instituted by the university to assist undergraduate students who have changed their minds about their original field of study or who have been judged unlikely to make satisfactory progress in their chosen field. Becoming a Transitional Student gives a

student an opportunity to maintain a relationship with the home college while re-orienting academic plans and goals. It also gives a student time to explore their options and/or enhance admissibility to another college in the university, or to another institution. Ordinarily, a student will be permitted to register as a Transitional Student for no more than one semester. In exceptional circumstances, a student may be allowed to extend the status beyond one semester. A student must obtain the permission of their home college associate dean to initiate this option.

Transitional Student status may be available to students upon the advice of their advisor, or at their own request. Interested students must make an appointment with the associate dean of their home college to discuss this option.

Note: Students at Carnegie Mellon in good academic standing may transfer from one program to another as long as they meet curricular or artistic requirements and as long as there is space in the program into which they wish to transfer.

New Degree, Major, or Minor

Departments proposing new degrees, majors, additional majors, and/or minors must complete a New Academic Program Process (NAPP Step 2) form. This should include any and all notations to the university diploma and/or transcript (new degrees, majors, minors, options). Departments proposing to offer a new degree, major, additional major and/or minor must follow university policies for approval as follows:

- Document the program by completing the New Academic Program Process (NAPP Step 2) form. Departments proposing new degrees and majors must complete this form and attach course descriptions, curriculum proposal, list of present faculty who will support the program, and verify the availability of other units' courses. This documentation must indicate the starting semester for the program, and in the case of new majors, also indicate if it is available only as a major/additional major/minor, or in combination.
- Receive department approval.
- Receive dean and College Council approval.
- Submit all program documentation complete with College Council approval to the Vice Provost for Education. New majors or degrees will not be processed without the approval of the Provost's Office.
- The Provost's Office will approve or deny, and inform the sponsoring department and Enrollment Services.
- The department may then publicize and offer the program for student enrollment.

Inter-campus Undergraduate Student Transfer Process

Undergraduate students enrolled at either the Pittsburgh or Doha campuses of Carnegie Mellon University may request consideration for internal transfer to the other undergraduate campus through a formal application process. Students must be in good standing with a QPA of 3.0 or higher, and must have completed two full semesters at their campus of initial enrollment. The first step in the process is consultation with the student's home campus Associate Dean for Education to fully discuss their potential interest in a transfer. Students will be required to document their interests and offer a compelling academic and/or personal rationale to support their inter-campus transfer request application. The deadline for application is the first day of the spring semester for transfer in the subsequent fall semester.

University Policies

A University Policy is a rule that has been officially sanctioned by the president of Carnegie Mellon University and that generally has university-wide applicability. A policy may include governing principles, may either mandate or constrain action, may ensure compliance with laws, or may mitigate the university's risk. Broadly, a policy is either academic or administrative in scope and application and must be approved by the president (and Board of Trustees as required), in order to become official University Policy.

Additional University Policies and information may be found at www.cmu.edu/policies (<https://www.cmu.edu/policies/>).

Academic Integrity

www.cmu.edu/policies/student-and-student-life/academic-integrity.html
(<https://www.cmu.edu/policies/student-and-student-life/academic-integrity.html>)

Students at Carnegie Mellon are engaged in intellectual activity consistent with the highest standards of the academy. The relationship between students and instructors and their shared commitment to overarching standards of respect, honor and transparency determine the integrity of our community of scholars. The actions of our students, faculty and staff are a representation of our university community and of the professional and personal communities that we lead. Therefore, a deep and abiding commitment to academic integrity is fundamental to a Carnegie Mellon education. Honesty and good faith, clarity in the communication of core values, professional conduct of work, mutual trust and respect, and fairness and exemplary behavior represent the expectations for ethical behavior for all members of the Carnegie Mellon community.

Policy Statement

In any manner of presentation, it is the responsibility of each student to produce their own original academic work. Collaboration or assistance on academic work to be graded is not permitted unless explicitly authorized by the course instructor(s). Students may utilize the assistance provided by the Student Academic Success Center and the Academic Resource Center (CMU-Q) unless specifically prohibited by the course instructor(s). Any other sources of collaboration or assistance must be specifically authorized by the course instructor(s).

In all academic work to be graded, the citation of all sources is required. When collaboration or assistance is permitted by the course instructor(s) or when a student utilizes the services provided by the Student Academic Success Center and the Academic Resource Center (CMU-Q), the acknowledgement of any collaboration or assistance is likewise required. This citation and acknowledgement must be incorporated into the work submitted and not separately or at a later point in time. Failure to do so is dishonest and is subject to disciplinary action.

Instructors have a duty to communicate their expectations including those specific to collaboration, assistance, citation and acknowledgement within each course. Students likewise have a duty to ensure that they understand and abide by the standards that apply in any course or academic activity. In the absence of such understanding, it is the student's responsibility to seek additional information and clarification.

Policy Violations

Cheating occurs when a student avails themselves of an unfair or disallowed advantage which includes but is not limited to:

1. Theft of or unauthorized access to an exam, answer key or other graded work from previous course offerings.
2. Use of an alternate, stand-in or proxy during an examination.
3. Copying from the examination or work of another person or source.
4. Submission or use of falsified data.
5. Using false statements to obtain additional time or other accommodation.
6. Falsification of academic credentials.

Plagiarism is defined as the use of work or concepts contributed by other individuals without proper attribution or citation. Unique ideas or materials taken from another source for either written or oral use must be fully acknowledged in academic work to be graded. Examples of sources expected to be referenced include but are not limited to:

1. Text, either written or spoken, quoted directly or paraphrased.
2. Graphic elements.

3. Passages of music, existing either as sound or as notation.
4. Mathematical proofs.
5. Scientific data.
6. Concepts or material derived from the work, published or unpublished, of another person.

Unauthorized assistance refers to the use of sources of support that have not been specifically authorized in this policy statement or by the course instructor(s) in the completion of academic work to be graded. Such sources of support may include but are not limited to advice or help provided by another individual, published or unpublished written sources, and electronic sources. Examples of unauthorized assistance include but are not limited to:

1. Collaboration on any assignment beyond the standards authorized by this policy statement and the course instructor(s).
2. Submission of work completed or edited in whole or in part by another person.
3. Supplying or communicating unauthorized information or materials, including graded work and answer keys from previous course offerings, in any way to another student.
4. Use of unauthorized information or materials, including graded work and answer keys from previous course offerings.
5. Use of unauthorized devices.
6. Submission for credit of previously completed graded work in a second course without first obtaining permission from the instructor(s) of the second course. In the case of concurrent courses, permission to submit the same work for credit in two courses must be obtained from the instructors of both courses.

Procedures for dealing with allegations of these policy violations are detailed in the university's Academic Disciplinary Action Procedures, which are published in The WORD student handbook (<https://www.cmu.edu/student-affairs/theword/>). Periodic review of these procedures will be overseen by the Dean of Student Affairs or her/his designee in consultation with Faculty Senate and the relevant student governing bodies. Any amendments to these procedures are subject to the approval of Faculty Senate. Additional guidelines and procedures for graduate students may exist at the college/department/program level, in which case they are communicated in the college/department/program graduate student handbook.

Computing Policy

www.cmu.edu/policies/information-technology/computing.html (<https://www.cmu.edu/policies/information-technology/computing.html>)

Statement

The purpose of this policy is to set forth guidelines so that members of our community may use the campus network and computing facilities in ways that are responsible and respectful of privacy. This policy sets forth the university's expectations of acceptable behavior on the part of computer systems users at Carnegie Mellon by providing guidelines for appropriate use of computing and related communication systems and examples of inappropriate use. These standards of acceptable behavior also extend beyond the campus community into the Internet. Just as it is unacceptable to violate others' rights to privacy, property and resources within Carnegie Mellon, it is also unacceptable to violate those rights on systems that are not at Carnegie Mellon but are accessible through Carnegie Mellon's connection to the Internet.

This policy applies to all users of Carnegie Mellon computing systems, including students, faculty and staff, and any others granted the use of university computing resources. It applies to the use of all computing facilities owned, leased, operated or contracted by Carnegie Mellon University. As used in this policy, terms such as "computing," "computing/communications systems," "computing resources," etc., refer to all computers, communication systems, and peripherals, software, telephones and systems with similar functions, which are owned by Carnegie Mellon, or which utilize Carnegie Mellon infrastructure such as telephone lines or computer networks.

Although this policy does not attempt to deal specifically with legal issues, university members are responsible to act in compliance with the law, including any federal, state and local laws governing computer and telecommunications use, as well as all other applicable university policies.

Privileges and Responsibilities

Every member of the Carnegie Mellon community who uses computing and related communications systems at Carnegie Mellon, or systems that belong to Carnegie Mellon or which rely on Carnegie Mellon's infrastructure has the responsibilities described in this policy. This includes members of the Carnegie Mellon community who have restricted privileges, such as alumni who may have electronic mail forwarding access, but no access to "login" resources. Individuals with personally-owned computers, but who rely upon the university network to connect those computers (either through an on-campus or remote network connection, such as Ethernet, wireless, dialup, DSL) are expected to abide by the policies set forth in this document. Personally-owned computers operating in stand-alone mode or networked through a non-university connection are not covered under this policy, but those users are encouraged to consult the usage policies set forth by their Internet Service Provider.

A fundamental premise of this policy is that anyone sharing computing resources with other individuals should behave as a reasonable, mature and ethical person. The user must recognize that computer systems and networks do not exist in some special rule-free environment; on the contrary, use of computers is a form of communication, and every component of a computing environment and every piece of information it contains belong to the university, the university community as a whole, or some individual or group within that community.

Access to Carnegie Mellon's computing resources is contingent upon being a member of the university community and adhering to university and Computing Services policies, guidelines and procedures, including this policy. Misuse may result in the loss of access and/or university disciplinary action. For some users and certain systems, access may be authorized by specific departments, research centers or other organizations affiliated with Carnegie Mellon. In such cases, any department- or group-specific policies and guidelines must be adhered to when using resources provided by the department or group. This is in addition to university policies and Computing Services guidelines and procedures.

Any user who suspects a violation of the University's computer use policies, or who has knowledge of potential vulnerabilities or security loopholes in a system or network at Carnegie Mellon, should immediately notify the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Maintain the Security and Confidentiality of your Account

Users assume personal responsibility for the use made of their computer accounts. This responsibility begins with selecting a secure password, and involves maintaining the confidentiality of that password and changing the password regularly in order to assure the continued security of your account. For guidance in selecting a secure password, see [Managing Your Andrew Password](#). If you believe that someone has made unauthorized use of your account, you should change your password immediately and report the incident to the Computer and Network Security Coordinator or abuse@andrew.cmu.edu.

Respect for Others' Property and Privacy Rights

Users are responsible to respect copyright agreements and intellectual property ownership. Any material that is the work of another, whether explicitly copyrighted or not, should not be distributed by a user without appropriate acknowledgement and/or permission of the creator; unless permission has been granted by the owner of copyright protected materials, distribution of copyright protected material via the university network or computer systems is prohibited. So while the university has been granted permission by software vendors to distribute certain software packages via the network, it is not generally permissible for individual users to distribute that same software to others via the university network or computer systems. See the sections in this policy on Misuse and Inappropriate Behavior. While there may be cases in which property rights to particular programs, data, etc., are ambiguous or in dispute, the user must assume that any information not created by themselves belongs to someone else and must respect that person's privacy and property rights to that information. (In certain situations, even information created by the user may not belong to that user but rather to the university or others.) This policy is not intended to limit "fair use" as permitted under the Copyright Act and users having questions about whether a particular use constitutes a "fair use" may consult the General Counsel for advice.

Improper/Illegal Communications

Any communications that would be improper or illegal on any other medium are equally so on the computer: libelous material, obscene messages, harassment, forgery, threats, etc. However, this is not intended to restrict the free expression of ideas. Communication conducted in accordance with the university policy on Free Speech and Assembly and Controversial Speakers and with the statement on Academic Freedom and Responsibility enunciated in the Appointment and Tenure Policy of Carnegie Mellon University will not be considered a violation of this policy. For further

guidelines, see also the university policy on Separation of Individual's and Institution's Interests.

Responsible Sharing of Resources

Where a resource such as memory, CPU time or access to network resources belongs to the whole community collectively, it must be shared.

It is unacceptable to make such excessive use of system or network resources that other users cannot obtain access. Examples include excessive use of CPU time during a period of heavy use on a timesharing system, excessive use of disk space on a system that does not limit such utilization, the use of an excessive amount of network bandwidth in an environment of networked computers, and any activity that makes a system unusable or significantly degrades performance for others. A novice user might be unaware that a particular action constitutes "excessive use" but, without doubt, once a system administrator makes them aware of the fact that such an action is unreasonable, that user will be held responsible for any further such infractions. If you are unsure whether your needs constitute excessive use, contact the system administrator. Similarly, if you need an unusual amount of disk space, CPU time or other resources, check with the system administrator to find out whether this use can be accommodated, rather than risk interfering with the work of others on the system.

Risks of Data Loss and Data Persistence

Although the university will make efforts to secure the network and university controlled servers from abuse and damage, it cannot guarantee against data loss by a student, faculty, member or staff, either on a university-operated or an individually-owned computer.

Users should know that even those files that they have "deleted" using the appropriate procedures in the application or operating system, may indeed be recoverable if they exist in a system backup file or other persistent form. If the university is asked to recover such data by subpoena, it must cooperate, and data that the user believes to have been destroyed may be recovered in the process.

Personal Use

While the university makes computer resources available primarily to achieve its goals of education and research, and for administrative activities, it realizes the need to encourage the personal use of computing for the convenience of the campus community. Thus, it is reasonable to allow the use of computing resources for computer mail, document preparation, personal or course Web page publication, or other activity that can facilitate convenience or enhance productivity, to the extent that the activity is within the limits described by Responsible Sharing of Resources.

Any personal use of computing resources related to operating a personal business or commercial enterprise is prohibited unless permission to do so has been specifically granted by the provost or the provost's designee.

We do recognize the difficulty of distinguishing whether certain cases of "personal use" are allowable, such as activities that result in personal financial gain (e.g. checking stock prices online), relate to a commercial business (e.g. university-sponsored technology transfer efforts), or support (but do not constitute operating) a personal business (i.e., a student developing a business plan or a faculty member writing a report for a consulting engagement outside the university). In such cases, we rely on individuals to be responsible and judicious in the use of university's shared computing resources. In particular ensuring:

- appropriate use of resources (e.g. any such work is completed outside of university time and does not utilize shared resources such as CPU cycles or network bandwidth to a degree that adversely impacts academic or research activities);
- appropriate use of licenses (e.g. do not use software procured with academic use licenses for commercial applications or development, unless the license explicitly permits such use);
- appropriate marketing (e.g. no creation of ".com" domains within Carnegie Mellon's "edu" domain, no advertising services and products using Carnegie Mellon email accounts, and no advertising using web pages on Carnegie Mellon servers (any server with a .CMU.EDU host name).

In cases of questionable personal use of resources, you may contact advisor+@andrew.cmu.edu to determine whether a particular activity is permissible.

We reserve the right to restrict personal use of university systems and networks by an individual or by the community at large, if the use of resources for such activities becomes excessive. If you need unlimited access to computer networks for private or business purposes, you can subscribe to a commercial service.

For information regarding the use of resources to produce intellectual property and profit from the development of such property see Carnegie

Mellon University's Intellectual Property Policy and the Policy on Conflict of Interest/Commitment.

Privacy

The user must presume that the contents of any other users' directory are private unless expressly designated otherwise, just as one would presume that the contents of someone's apartment or office are private.

The only exceptions to this rule are: that in some environments, files such as "plan files" may be considered public even if the user has not expressly designated them as such; and that some services such as web pages and anonymous or "guest access" ftp services may be considered to be public, but only for those areas not protected by password and which are "obviously" public. An unprotected account or shared device (such as a shared disk on a networked computer) are not considered to be public unless the name or service expressly indicates that it is. In such cases, any files or other data which would appear to be private in nature, by virtue of the file name or data stored, even if "publicly accessible" should be considered to be private. The user accessing such files has a responsibility to ask the owner of the files or service if the files are intended to be publicly accessible before the user does more than a " cursory glance" sufficient to cause the question.

A user can explicitly grant access to his or her directories, files or to services run from his or her systems. However, users who issue general or vague invitations to browse through their files incur a special obligation to protect any material that they do not wish others to see. Indeed, all users are urged to maintain protection levels on their files consistent with the access they are actually willing to give to other users.

Access to Faculty Data

Electronic data on a faculty member's account, whether stored on a computer in the faculty member's office or elsewhere under the proprietary control of that faculty member, may not be examined, i.e., the contents of the data read by a person, without the faculty member's consent, except in cases of emergency or in response to a valid subpoena, search warrant, or order of a court. Posting of data by a faculty member on servers available to the public or to students shall be understood to imply consent, and electronic access given to specific parties by the faculty member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the faculty member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the faculty member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith, and, whenever possible and legally permissible, sufficient time must be allowed, before intrusion, to allow the faculty member to file a motion to quash. Information obtained from an examination warranted by an emergency cannot be used as evidence in University sanctions of any faculty member, and cannot be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any intrusion by an employee of the University into a faculty member's electronic data must be reported to the faculty member as soon as possible, and within five days of the event in writing both to the faculty member, if possible, and unless prohibited by order of court, and to an Ombudsman, who shall be a member of the regular faculty selected annually by the Nominating Committee of the Faculty Senate and who has been endorsed by majority vote of the Faculty Senate. The Ombudsman shall be a current or retired regular faculty member who holds no administrative appointment and is not a member of the Faculty Review Committee. The Ombudsman shall have authority to investigate whether an intrusion was warranted by the policy and, (i) shall inform the President and the affected faculty member of the Ombudsman's findings; (ii) where a violation of the policy is found, shall inform the Faculty Review Committee of the policy violation; and (iii) where appropriate, in the absence of the affected faculty member, to bring a grievance before the Faculty Review Committee. Violation of any aspect of this policy is a sanctionable offense.

For purposes of this section, the term "faculty" shall mean any person who is a member of the Faculty Organization as defined in Article III of the Constitution of the Faculty Organization.

Access to Staff Data

Electronic data on a staff member's account, whether stored on a computer in the staff member's office or elsewhere under the proprietary control of that staff member, may not be examined, i.e., the contents of the data read by a person, without the staff member's consent, except in cases of emergency, in response to a valid subpoena, search warrant, order of a court, or by specific request by the staff members' supervisor for the purpose of accessing work-related electronic data. Posting of data by a staff member on servers available to the public or to members of the university shall be understood to imply consent, and electronic access given to specific parties by the staff member will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the staff member, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency." Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the staff member whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime concealment of which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any such findings may be reported to the staff member's supervisor, department head, or to Human Resources for appropriate investigation and action. Any intrusion by an employee of the University into a staff member's electronic data must be reported to the staff member as soon as possible, and within five days of the event via electronic mail unless prohibited by order of court, or due to a continuance of an ongoing investigation by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, staff members will be informed about the issuance of court orders, or other intrusions into their electronic data. In cases where a staff member believes that electronic data in their account has been inappropriately accessed by another staff member, the incident should be reported to Human Resources.

Access to Student Data

Electronic data stored in a student account, whether stored on a computer in the student's residence or elsewhere under the proprietary control of that student, may not be examined, i.e., the contents of the data read by a person, without the student's consent, except in cases of emergency or in response to a valid subpoena, search warrant, order of a court, or by order of the Office of the Dean of Student Affairs. Posting of data by a student on servers available to the public shall be understood to imply consent, and electronic access given to specific parties by the student will likewise imply consent for those parties to access permitted data. Emergencies may include, for example, but are not limited to, the death, incapacity or disappearance of the student, or the search for and examination of files used for apparently malicious activity in an account which endangers the integrity of shared computers, the network, or other aspects of the university's computing infrastructure.

Only specifically designated individuals are permitted to determine what passes for an "emergency". Such individuals may be specifically designated, or may be designated by job position/description. All assignments for individuals or positions will be done by Provost or by a designate of the Provost.

Whenever possible and legally permissible, notification must be given to the student whose data are subject to subpoena, search warrant, or order of court prior to compliance therewith. Information obtained from an examination warranted by an emergency will not be released to the public, or to the university community or to public officials, except as such releases are essential to resolution of the emergency, or constitute evidence of a crime of concealment which would obstruct justice, and in the latter case release may only be to appropriate law enforcement officials. Any findings of potential wrongdoing unrelated to the original intent of the search, must be reported to the Office of the Dean of Student Affairs for appropriate investigation and action. Any intrusion by an employee of the University into a student's electronic data must be reported to the student as soon as possible, and within five days of the event via electronic mail to the student, if possible, unless prohibited by an order of the court or because of an ongoing investigation conducted by the University. Violation of any aspect of this policy is a sanctionable offense.

When possible, students will be informed about the issuance of court orders, or other intrusions into their electronic data, including the purpose of the

search. In cases where a student believes that electronic data in their account has been inappropriately accessed by a staff member, the incident should be reported to Office of the Dean of Student Affairs.

Note: Removable media such as floppy disks, zip drives, tapes, or CDs in a faculty or staff office, or in a residence hall are not subject to search by Computing Services, though Computing Services will assist authorized law enforcement agencies or authorities to read data after they are obtained, at the agencies' or authorities' request.

Protecting Confidential Information

Users who maintain confidential information, such as records relating to employees or students, are responsible for following privacy-related policies and laws.

Protecting Personal Information

As is described throughout this policy, data transmitted across the university network or stored on university systems may be accessed by others as a result of misuse by an individual, as an incidental result of the routine operation of the network and systems, or in response to a court subpoena or university investigation into suspected or alleged misuse. While complete privacy of personal data may not be possible, users who wish to ensure a higher degree of privacy for their data are encouraged to use encryption, PGP security, or other techniques to reduce the risk that others may access their data. For more information on these techniques, see various newsgroups (e.g. comp.security.pgp) or web references (e.g. comp.security.pgp FAQ).

Misuse and Inappropriate Behavior

The following activities are expressly prohibited at Carnegie Mellon:

- Using a computer system without proper authorization granted through the University, college, or department management structure. Some activities such as "port scanning" are not expressly prohibited. However, if the target of such scanning requests that an individual or system stop performing such actions, the person or system performing the scans must stop scanning the target machine unless the scans are being carried out by a system administrator who has the authority and responsibility over the machine(s) being scanned or for the network being used.
- Concealing your identity, or assuming the identity of another (e.g., by sending forged electronic mail). Note that some forms of electronic communication, such as browsing Web pages, passively "identify" users. Keeping your identity private either by not setting an identity in your browser or by using a Web-anonymizer in order to protect yourself from being put onto mailing lists is not a violation of this policy.
- Sharing your password or account with the specific exception of staff or faculty members allowing their support personnel to access their accounts in order to provide services appropriate to their job functions. Note that some policies for the accessing of specific systems or data (see Data and Computer Security, Confidentiality of Administrative Data) explicitly forbid the sharing of passwords used to access them, and that such restrictions for those specific systems override this policy.
- Using another person's computer account, userID, files, or data without appropriate permission, as described in the previous bullet (e.g. using an account found "logged in" on a cluster machine).
- Deleting or tampering with another user's files or with information stored by another user on any information-bearing medium (disk, tape, memory, etc.). Even if the user's files are unprotected, with the exception of files obviously intended for public reading, such as Web pages, it is improper for another user to read them unless the owner has given permission (e.g. in an announcement in class or on a computer bulletin board).
- Attempting to "crack" or guess other users' passwords. System administrators or those specifically designated by the administrator or owner of a system may attempt to crack passwords in order to test and enhance the security of the system. In cases where an individual or department "owns" machines which use password files controlled by another organization (e.g. Andrew machines or their like), the owner may not attempt to crack passwords without explicit permission by the owners of the password database.
- Obtaining passwords by other means, such as password capturing programs.
- Attempting to circumvent system security (e.g. breaking into a system or using programs to obtain "root" access), without the explicit permission of the owner of that system.
- Denying appropriate access to resources to other users (e.g. "ping flooding" another system, sending "mail bombs," or modifying a login file in order to cause a user to not be able to log in).

- Releasing programs such as viruses, Trojan horses, worms, etc., that disrupt other users, damage software or hardware, disrupt network performance, or replicate themselves for malicious purpose.
- Sending commercial solicitations via electronic mail (i.e. spamming) to individuals, or to newsgroups or mailing lists where such advertising is not part of the purpose of the group or list. (It is permissible to send a commercial solicitation to a "for sale" newsgroup, provided that the advertisement conforms to other policies and guidelines at Carnegie Mellon.)
- Any "mass mailing" which is solicitous in nature, unless the mailing is in the conduct of university business.
- Reselling of services based on the university network, such as web hosting, mailing services or the selling of shell accounts.
- Running a proxy server which results in inappropriate or unauthorized access to university materials to non-university members.
- Advertising commercial businesses or ventures on Web pages hosted by Carnegie Mellon, unless prior authorization has been granted.
- Using mail messages to harass or intimidate another person (such as by repeatedly sending unwanted mail or broadcasting unsolicited mail).
- Violations of any local, state or federal laws, such as the distribution of copyright-protected materials (e.g. the distribution of commercial software, music or films in electronic format without appropriate permissions by the owner, even if the user distributing the materials notifies others of their copyright status).
- Tampering with, willful destruction of or theft of any computer equipment, whether it belongs to the university or to an individual. Tampering includes any deliberate effort to degrade or halt a system, to tie up a system or to compromise the system/network performance. Willful destruction includes any deliberate disabling or damaging of computer systems, peripheral equipment such as scanners or printers, or other facilities or equipment including the network, and any deliberate destruction or impairment of software or other users' files or data.
- The unauthorized removal of university or another's computing equipment, which constitutes theft.

This list should not be considered to be complete or exhaustive. It should, however, serve as a set of examples of obviously inappropriate behaviors. If you are in doubt about the appropriateness of something that you want to do, contact the Computing Services Help Center at 8-HELP, or send mail to advisor+@andrew.cmu.edu and ask first.

Enforcement

Inappropriate behavior in the use of computers is punishable under the general university policies and regulations regarding faculty, students and staff. The offenses mentioned in this policy range from relatively minor to extremely serious, though even a minor offense may be treated severely if it is repeated or malicious. Certain offenses may also be subject to prosecution under federal, state or local laws.

Appropriate disciplinary action depends not only on the nature of the offense, but also on the intent and previous history of the offender. The range of possible penalties includes reprimands, loss of computing privileges, course failures for students, disciplinary probation, suspension or dismissal from the university and/or criminal prosecution.

Offenses that are minor or appear to be accidental in nature are often handled in a very informal manner such as through electronic mail. More serious offenses will involve formal procedures pursued through the Division of Student Affairs for students, Human Resources and/or the hiring university department or administrative unit for staff, or the Faculty Review Committee for faculty.

Restrictions of Privileges During Investigations

During the course of an investigation of alleged inappropriate or unauthorized use, it may be necessary to temporarily suspend a user's network or computing privileges, but only after determining there is at least a prima facie case against the individual, as well as a risk to the university or its computing resources if privileges are not revoked. In these cases, it is important to recognize that the restriction of network or computing privileges is intended to protect the system rather than to punish the individual. For example, if a computer account has been used to launch an attack on another system, that account will be rendered inactive until the investigation is complete. This is a necessary action taken to prevent further misuse and does not presume that the account holder initiated the misuse. Unsubstantiated reports of abuse will not result in the suspension of accounts or network access unless sufficient evidence is provided to show that inappropriate activity occurred. For example, if someone reports that their computer was "attacked" by a Carnegie Mellon system, the burden will be upon the complainant to provide sufficient data logs or other evidence to show that the incident did, indeed at least appear to be an attack.

Adverse Impact on Shared Systems

The university reserves the right to discontinue communication with external systems that are known to harbor spammers or account crackers, despite the fact that this may restrict certain acceptable communications. When deemed necessary, this action will be taken to protect the security and safety of our systems. Similarly, there may be cases where a particular service or activity on a given University system will, by the very nature of its legitimate operation, tend to generate attacks from other Internet sites. If these attacks are frequent and severe enough to cause service interruptions for larger parts of the campus community, it may be necessary to temporarily or permanently remove these systems from the campus network. In cases where such an action is deemed necessary, network administrators will work with the maintainers of the system to identify alternative methods of network access. In cases where the university restricts access to external sites or removes network access for internal sites, the purpose of the action is to maintain the security and reliability of the computer systems and networks rather than to punish an individual or a site, or to restrict the free expression of ideas.

Policies on Examinations

www.cmu.edu/policies/student-and-student-life/examination-policies.html
(<https://www.cmu.edu/policies/student-and-student-life/examination-policies.html>)

Preamble

The Faculty Senate adopted the following policies on the administration of examinations for the undergraduate courses (defined as courses that are numbered 6xx or below). These policies represent an understanding between faculty and student concerning an important but often stressful period, especially at the conclusion of each academic semester and at mid-semester. There should be no expectation that the following points will cover every conceivable situation. The student should anticipate the demands of the exam schedule, plan accordingly and early, and be prepared. The faculty should recognize that the student is encumbered with many tightly orchestrated and intensive obligations during this period over which they have no control: expectations should be reasonably consistent with the number of course units and, of course, should be made known to the student well in advance of the final examination period, preferably as part of the course syllabus.

In order to help students plan their time and study optimally for examinations, this document lays out in some detail the policies regarding final and in-term examinations. Instructors are requested to provide notification of the major in-term examinations in the course syllabus. The final examination date is posted early in the semester. It is the responsibility of the student to give his or her instructor sufficient notice and to work with the instructor to reschedule examinations if this is needed.

Definitions

- Final examination period. The university's official final examination period begins on the Monday immediately following the last day of classes and continues through the last day of scheduled final examinations, with the exception of reading day(s).
- Scheduled final examinations. Scheduled final examinations are those scheduled by Enrollment Services.
- Self-scheduled examinations. An instructor may choose not to fix a schedule for the final examination, but instead allow each student to choose the examination time; such exams are called self-scheduled examinations.
- Final examinations. Final examinations can either be comprehensive, covering all course materials, or non-comprehensive, covering only a part of the course.
- In-term examinations. Major examinations during the semester are referred to here as in-term examinations.

I. In-Term Examinations

1. All in-term examinations should be given during the regularly scheduled class time. However, if the exam requires additional time to complete, then examinations may be administered outside of regularly scheduled class time.
2. No examinations given outside of class time (excluding make ups and self-scheduled examinations) shall be administered on a Friday after 4:30 pm, or at any time Saturday or Sunday.
3. The instructor administering an exam (or another required class event) that falls outside class time must make any and all reasonable accommodations to provide an alternative time to students who have conflicts with the proposed time period, including those conflicts due to

activities, meetings, other classes, etc. (provided that the instructor is notified of such conflict in a timely manner).

4. No student shall be required to take more than two full-period in-class or out-of-class examinations on the same day. It is the responsibility of the student to notify the instructor in a timely manner of their circumstance so that appropriate accommodations can be made.

II. Final Examinations

1. All scheduled final examinations are held at the end of the semester during the university's official final examination period. Comprehensive final examinations are not required for each course, but are given at the option of the department or instructor. The reading day and weekend preceding the examination days shall never be used for examination purposes of any kind, unless a student opts to take a self-scheduled examination during this time. Non-comprehensive final examinations or final projects (but not both) are allowed during this final examination period only in courses that do not give a final comprehensive examination.
2. Instructors are expected to return all work assigned no later than the last regular day of classes in courses for which there is a final examination. In cases when this is not possible, an answer key, solution sets or equivalent feedback should be provided unless the final examination will not cover material in work that has not been returned.
3. No other coursework, including laboratory or studio work, will be due during the final examination period unless it is assigned in advance and in lieu of the course's final examination. Regardless of whether there is a final examination in the course, no classes other than review sessions shall be held during the final examination period. Review sessions should be scheduled for optimal attendance, and a serious effort should be made to accommodate students who cannot attend. In appreciation of the time required to prepare for final examinations, no other examinations, portfolio reviews, critiques or juries shall be scheduled for the last class day of a course with a final examination.
4. Instructors shall never exert or submit to pressures to move an examination so that people can leave earlier nor pressure students to take an examination on a reading day or weekend preceding examinations.
5. No student is required to take more than two scheduled examinations that start within a 25-hour period. A student who has more than two examinations scheduled within a 25-hour period or has two examinations scheduled at the same time should first contact the instructors of the courses for assistance in resolving conflicts. If the problem cannot be resolved by that means, the student should contact the associate dean of his or her home college.
6. Take-home final examinations shall be given for any 24-hour period of the student's choosing during the final examination period.
7. Students are expected to present themselves at the place assigned at the start of the examination; late arrival will reduce the total time a student has to complete the examination, unless instructor's course policy indicates otherwise. Instructors reserve the right to require attendance within a specific time period. Students who miss an examination with a reasonable excuse and wish to petition for a make-up final examination should check with the instructor. Instructors are encouraged to include late arrival policy and make-up exam policy in the course syllabus.
8. Any student shall be permitted to review his or her corrected, graded final examination in the presence of an instructor or a teaching assistant. Any controversy arising from this review shall be dealt with in accordance with the university procedure for the appeal of grades and academic actions. A final examination that is not returned to a student will be kept available for a year for review. In the event that the instructor or teaching assistant is not available for the review, the responsibility shall rest with the department head of the instructor offering the course or his or her designee. Since instructors are expected to return all work assigned before the final examinations, they are not responsible for retaining unclaimed coursework.
9. Concerns related to final examination, complaints about violations of the final examination policy or alterations of the final examination schedule should be directed to the department head of the instructor offering the course or to the associate dean of the student's home college.

Contact

Questions concerning this policy or its content should be directed to the Vice Provost for Education, (412) 268-5865.

Final Examination Conflict Guidelines

Recognizing that students will, on occasion, encounter foreseeable or unforeseeable conflicts with scheduled final examinations, the following guidelines have been approved by the University Education Council (UEC),

the Associate Deans' Council (ADC), and the Associate Deans for Graduate Programs (ADGP) to inform the actions of students and the decisions of instructors.

Foreseeable Conflicts:

Before negotiating any exam conflicts, students should recognize the following expectations. Students should carefully consider the dates of each semester's final exam period as reflected in the university's official academic calendar. Until the university publishes the detailed final examination schedule (usually by early October in the Fall semester and by late February in the Spring semester), students should plan according to the assumption that their final exams could be scheduled for any day/time during the final exam period. Therefore, students should avoid making any personal arrangements (such as travel) that could ultimately conflict with the final exam period.

In developing the final examination schedule, the University Registrar's Office deploys significant effort in consultation with associate deans to minimize direct and 25-hour conflicts for individual students. Once the final exam schedule is published for the semester, each student should immediately review the schedule to determine whether there are conflicts. If the student's schedule presents any final exams that directly conflict with each other, or if the student's schedule presents more than two final exams to begin in a twenty-five hour period, then the student is responsible for immediately initiating the following process so that the relevant instructors can reach a timely and effective resolution that is consistent with university policy (noting that no action is necessary if a student voluntarily elects to take the exams according to the published schedule):

1. The student should begin by discussing the conflict with all relevant instructors to determine if they can suggest a resolution. This discussion should be completed at least two weeks prior to the exams.
2. If one of the course instructors offers an alternate time for the exam, the student must agree to that resolution unless another exam conflicts with the alternate proposed time.
3. If a resolution cannot be found, the following hierarchy is recommended for compromise (Student's Home Department > Student's College > Smallest Course Size > Higher Course level):
 - If one of the courses is offered in the student's home department, the home department should be the first to accommodate.
 - If the course is offered within the student's home college, then the student's college should accommodate a course that is not within the student's college.
 - An instructor teaching a smaller course size should accommodate before an instructor from a larger course size accommodates.
 - Finally, if a resolution still has not been reached, an instructor teaching a higher course level should accommodate before an instructor from a lower course level accommodates.

At any point during this process, the student's academic advisor or academic associate dean from the home academic college may be consulted to verify the existence of the conflict and assist in the negotiation and resolution.

Other foreseeable conflicts may be personal in nature, such as a religious holy day or observance, or a singular, significant obligation. As stated earlier, students are expected to review the final exam schedule as soon as it is published to identify such conflicts. A student faced with such a conflict should first exhaust all reasonable means to otherwise resolve it.

If such efforts are unsuccessful, then the student should immediately contact the instructor and explain the circumstances, recognizing that the current Policy on Examinations (<https://www.cmu.edu/policies/student-and-student-life/examination-policies.html>) does not require the instructor to offer an alternate exam time in response to foreseeable, personal conflicts.

The mutual respect and goodwill between instructor and student should guide their negotiation of such conflicts as they attempt to balance the student's needs with those of the academic enterprise. At any point in the process, the student's academic advisor, academic associate dean and/or student affairs liaison may be consulted to assist in identifying reasonable accommodations or solutions.

Students hoping to resolve cases involving foreseeable conflicts should expect that their instructors may require them to take a rescheduled final examination on the Make Up Final Exam Day (<https://www.cmu.edu/hub/registrar/exams-and-grading/make-up.html>).

Unforeseeable Conflicts

In exceptional circumstances, a student may encounter a medical, personal or family emergency that unexpectedly interferes with their ability to participate in a scheduled final examination. When encountering such a

situation, the student should contact the instructor as soon as is reasonably possible, and ideally before the final examination has been administered.

The student's academic advisor, academic associate dean and/or student affairs liaison may serve as both advocate for the student and point of verification for the instructor. After reviewing the matter, should an accommodation be granted by the instructor, the instructor may elect to institute one of several options, including: rescheduling the exam for later in the final examination period; assigning an "I" incomplete grade until a make-up exam can be administered in the following semester; or utilizing another method for resolving missed exams that has been outlined in the course syllabus.

Student Health Insurance Policy

www.cmu.edu/policies/student-and-student-life/student-health-insurance.html (<https://www.cmu.edu/policies/student-and-student-life/student-health-insurance.html>)

Reason for Policy

The high cost of health care in the United States presents a potentially serious health and financial risk to students and their accompanying dependents. The absence of adequate insurance coverage can result in temporary or permanent interruption of a student's education. The university is committed to offering student health insurance that provides access to quality health care and achieves a balance between premium cost and adequate coverage without overburdening students' financial resources. This balance is best achieved through a mandatory/hard waiver insurance program that mitigates the effect of adverse selection.

Policy Statement General Requirements

All full-time students are required to carry health insurance and will be assessed a charge for the individual basic mandatory plan offered through the university student health insurance program. The charge will appear on the invoice of the first semester of attendance in the academic cycle. The student is required to take one of the following three actions:

1. Enroll in the basic plan as charged.
2. Upgrade the benefit plan by enrolling in the enhanced student health insurance options during the open enrollment period.
3. Apply for a waiver from the mandatory plan.

Requirements for Waiver

Application for a waiver from the university student health insurance plan must be made to Student Health Services by the last day of the open enrollment period. Students applying for waiver must provide documentation of continuing coverage verifying that they are enrolled as the dependent, partner/spouse or principal in an employer or government-sponsored insurance plan. Additionally, the plan must meet minimum standards for coverage as set forth below:

- It must offer at least 75% coverage for inpatient and outpatient medical services in the Pittsburgh area.
- It must include mental health benefits.
- The deductible must not exceed \$500 per accident or illness.
- It must offer medical benefits of at least \$50,000 per accident or illness.
- It must cover pre-existing conditions.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Carnegie Mellon Freedom of Expression Policy

www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html (<https://www.cmu.edu/policies/administrative-and-governance/freedom-of-expression.html>)

Freedom of Expression Policy

Carnegie Mellon University values the freedoms of speech, thought, expression and assembly - in themselves and as part of our core educational and intellectual mission. If individuals are to cherish freedom, they must experience it. The very concept of freedom assumes that people usually choose wisely from a range of available ideas and that the range and implications of ideas cannot be fully understood unless we hold vital

our rights to know, to express, and to choose. The university must be a place where all ideas may be expressed freely and where no alternative is withheld from consideration. The only limits on these freedoms are those dictated by law and those necessary to protect the rights of other members of the university community and to ensure the normal functioning of the University.

Rights

On Carnegie Mellon's Campus, anyone may distribute printed material, offer petitions for signature, make speeches, and hold protests or demonstrations outside university buildings. All such activities must be peaceful, avoiding acts or credible threats of violence and preserving the normal operation of the university. No event shall infringe upon the rights or privileges of anyone not in sympathy with it, and no one will be permitted to harm others, damage or deface property, block access to university buildings or disrupt classes. The enforcement of these conditions will not depend in any way on the message or sponsorship of the act or event. When guests are invited by a recognized campus organization, they may express their ideas not because they have a right to do so, but because members of the campus community have a right to hear, see, and experience diverse intellectual and creative inquiry. Defending that right is a fundamental obligation of the university. Controversy cannot be permitted to abridge the freedoms of speech, thought, expression or assembly. They are not matters of convenience, but of necessity.

Responsibilities

Freedom of expression must be at once fiercely guarded and genuinely embraced. Those who exercise it serve the Carnegie Mellon community by accepting the responsibilities attendant to free expression. University organizations that sponsor invited guests to campus are expected to uphold Carnegie Mellon's educational mission by planning carefully to create safe and thoughtful experiences for those involved. Hosts are responsible for the behavior of their guests and should exercise due care to ensure that all participants abide by relevant university policies.

Considerations for Planning Campus Events

Consistent with the rights and responsibilities outlined in the university's policy on Freedom of Expression, university hosts must follow all applicable policies related to space reservation, use, safety and security, keeping in mind the responsibility to have campus police present for any event with 100 or more persons in attendance.

Hosts should consider the items below as guidance in planning campus events, recognizing that not all of the items will apply to all events:

1. A public declaration of the event, its purpose, the identification of sponsors and co-sponsors, and contact information for those seeking further information.
2. A plan for advertising the event, including advance notice to relevant members of the community who may wish to co-sponsor, protest, or host other events in response to the planned activity.
3. Where appropriate, a clear and detailed contract with outside speakers, artists, or suppliers of services to ensure continuity of purpose and the ability of the host to control the event reasonably, consistent with the host's intent.
4. A plan for access to the event, including notifying the community of reserved seats, ticketing, queuing protocol, or other relevant details or restrictions well in advance of the activity.
5. A provision for security before, during, and after events, managed in coordination with the University Police. Specifically, non-university security personnel must have their allowable duties clearly delineated, in partnership with the University Police, with their role generally limited to personal security and not to space management.
6. A plan for participant engagement at the event, such as through a question and answer session, if relevant, with a clear delineation of the planned ground rules for the event set out well in advance.
7. A strategy for hosting of additional events, discussions, or town meetings before or after a principal event to help provide a context in which the principal event may be best experienced.

The Office of Student Activities and the Office of the Dean of Student Affairs may assist in, or directly coordinate, some aspects of campus events, such as fostering discussions preceding or following an event, or accommodating an opposing view at an alternative event. It is assumed that the spirit of community, both among people with groups with opposing views, as well as between event sponsors and the Student Activities and Student Affairs staffs, will foster communication and cooperation in the planning of campus events. Wherever possible, Student Affairs will work in concert with

University Police to notify occupants of buildings in advance of any potential disruption caused by such events.

Security Personnel Statement

At times, members of the campus community or their invited guests may have a legitimate basis for being accompanied by independent security personnel. It is incumbent upon the host of such an individual to ensure that University Police approve in advance the presence and scope of involvement of any such security personnel.

Human Subjects in Research at Carnegie Mellon

The university is committed to the protection of the rights and welfare of human subjects in research investigations conducted under the jurisdiction of the university. The university believes that review independent of the investigator is necessary to safeguard the rights and welfare of human subjects of research investigations. All research involving human subjects is conducted in accordance with federal regulations, including Title 45 of the Code of Federal Regulations, Part 46 (45 CFR 46). Under federal regulations, human subjects are defined as: living individual(s) about whom an investigator conducting research obtains:

- data through intervention or interaction with the individual, or
- identifiable private information.

An Institutional Review Board (IRB) is established under the provost to ensure adequate safeguards. The provost is responsible for the composition of the IRB with respect to: (1) the qualifications of IRB members in terms of educational background and research or other relevant experience, and (2) broad representation of relevant university interests.

This IRB is responsible for reviewing investigational procedures involving human subjects prior to the initiation of the research procedure in reference to (1) the rights and welfare of the individuals involved, (2) the appropriateness of the methods used to obtain informed consent, and (3) the risks and potential benefits of the investigations. The IRB is responsible for determining when additional expertise is required for adequate review and for obtaining that additional expertise. The IRB is further responsible for maintaining records of its review activities and decisions and for ensuring that records of informed consent are developed and kept by investigators where appropriate.

It is the responsibility of investigators who plan to use human subjects in research to obtain written consent from the IRB prior to conducting an investigation involving human subjects. It is the investigator's further responsibility to take whatever steps are determined necessary for the protection of the subjects, and to meet the reporting requirements established by the IRB.

Student Immunization Policy

www.cmu.edu/policies/student-and-student-life/immunizations.html (<https://www.cmu.edu/policies/student-and-student-life/immunizations.html>)

Reason for Policy

Vaccine-preventable diseases continue to occur on American campuses and pose a significant threat to the public health of the campus community. Outbreaks not only impose a significant cost to infected individuals in terms of mortality and morbidity but also can be costly to the university by disrupting university activities.

Policy Statement

The goal of the Student Health Services and the university is to provide adequate protection of the campus community against vaccine-preventable diseases by requiring students to be vaccinated against and/or screened for certain highly contagious diseases. This goal can best be achieved through a mandatory prematriculation immunization requirement. The following requirements are consistent with Pennsylvania State Law and with the recommendations of the American College Health Association, the Advisory Committee on Immunization Practices.

Requirements for All Full-Time Students

All entering full-time students born after 1956 must demonstrate proof of immunity against measles, mumps and rubella by either providing dates of inoculation of two doses of the measles vaccine and at least one dose of mumps and rubella or providing blood titers that demonstrate immunity to these infections or providing documentation from a physician of having had the infection.

Additional Requirements for Students Residing in University Housing

- All students residing in university housing must demonstrate immunity against Hepatitis B by either providing documentation of having initiated or completed the three dose vaccination series.
- The student is expected to complete the series within six months of initiation of the series.
- All students residing in university housing must provide documentation of having been vaccinated against meningococcal meningitis within three years prior to enrollment in the university.
- All full-time international students must provide documentation of having had a PPD skin test to screen for tuberculosis within one year prior to enrollment in the university regardless of prior BCG inoculation. If the results of the skin test are positive, a chest x-ray is required.

Request for Waiver

- A student may request a waiver from any vaccination for medical reasons or if vaccination conflicts with personal or religious beliefs. Application for waiver is to be made in writing to Student Health Services prior to the first day of classes in his/her first semester of attendance at the university. In the case of an outbreak of a contagious disease on campus for which the student has not been immunized, the university reserves the right to ask the student to leave campus until the outbreak is over.
- A student may request a waiver from tuberculin skin testing if the student is from a country that has been identified by the Centers for Disease Control as having low prevalence of tuberculosis.

Penalty for Noncompliance

- If the student fails to comply with the immunization policy, the Student Health Services will notify Enrollment Services who will place a hold on the student's registration until the requirements are met and assess a fee of no more than \$50 to the student's account.
- Additionally, if the student is a resident in university housing and fails to comply with the immunization requirements, they will be removed from housing.

Contact

Questions should be directed to Student Health Services at 412-268-2157.

Related Policies and Procedures

The university complies with OSHA regulations regarding occupational exposure to blood-borne pathogens. Questions regarding these regulations should be directed to Environmental Health & Safety at 412-268-8182.

Additional recommendations

A PPD skin test for tuberculosis is recommended for domestic students who have traveled to an area where tuberculosis is endemic. All students should have a booster dose of tetanus/diphtheria every ten years after completion of the primary series.

Intellectual Property Policy

www.cmu.edu/policies/administrative-and-governance/intellectual-property.html (<https://www.cmu.edu/policies/administrative-and-governance/intellectual-property.html>)

1. Purpose

The policy reflects the following goals:

- To create a university environment that encourages the generation of new knowledge by faculty, staff, and students.
- To facilitate wide transfer of useful inventions and writings to society.
- To motivate the development and dissemination of intellectual property by providing appropriate financial rewards to creators and the university, and administrative assistance to creators.
- To ensure that the financial return from the development of intellectual property does not distort decisions and operations of the university in a manner contrary to the mission of the university.

The policy is based upon the following principles relating the university to society:

- The mission of the university remains the generation and dissemination of knowledge.
- Intellectual property will be generated within the university, and there exists an obligation to disseminate it. An interface is needed if better technology transfer is to be achieved, and the university will provide mechanisms for that function.

The policy is based upon the following principles relating faculty, staff and students to the university:

- Intellectual property is created by individuals, or by groups of individuals, who are entitled to choose the course of disclosure; academic freedom of individuals is a higher priority than possible financial rewards.
- There exists a historical tradition allowing authors to retain ownership of intellectual property rights from textbooks and works of art.
- The university is the support of the whole campus community, and is thereby entitled to share in financial rewards.
- There should be incentives for all parties to pursue financial rewards together, consistent with the expressed goals of the policy. The distribution of these rewards should reflect, insofar as possible, the creative contributions of the creator, and the resources contributed by and risks assumed by both the creator and the university in developing intellectual property.
- Since it is frequently difficult to assess risks meaningfully, resources and potential rewards, negotiated agreements are to be encouraged whenever possible.

2. Definitions

Certain terms are used in this document with specific meanings, as defined in this section. These definitions do not necessarily conform to customary usage.

Intellectual Property includes any patentable invention, any copyrightable subject matter, or trade secret. It also includes works of art, and inventions or creations that might normally be developed on a proprietary basis.

University means Carnegie Mellon.

Student means any full-time or part-time graduate or undergraduate student, regardless of whether the student receives financial aid from the university or from outside sources. It is the responsibility of students who are also employees of other outside entities to resolve any conflicts between this policy and provisions of agreements with their employers prior to beginning any undertaking at the university that will involve the development of intellectual property.

Faculty means members of the university's Faculty Organization as defined in the Faculty Handbook, plus instructors and special faculty appointments (even in the first year), and part-time faculty.

Staff means any employee of the university other than students and faculty as defined above. If a student is also a part-time university employee, he is considered as staff with regard to intellectual property developed as a result of his employment, and as a student with regard to other intellectual property. A full-time non-faculty employee who is also taking one or more courses is considered to be staff. Visitors to the university who make substantial use of university resources are considered as staff with respect to any intellectual property arising from such use. (The distinction between faculty and staff does not affect intellectual property rights except for representation on the Intellectual Property Adjudication Committee [see Section 5].)

Creator means any person or persons who create an item of intellectual property.

Net proceeds to the university means all proceeds received by the university on intellectual property that it assigns, sells or licenses, minus any application, litigation, interference, or marketing costs directly attributable to the intellectual property being licensed. Deducted costs shall be reasonable and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Net proceeds to the creator means all proceeds received by the creator from intellectual property owned by him that he sells, assigns or licenses, less the costs of application, legal protection, or litigation, interference, travel and other marketing costs directly attributable to the intellectual property being exploited. Such net proceeds do not include compensation legitimately received by the creator for consulting services or interest or other return on invested labor or capital. Deducted costs shall be reasonable

and fair, and shall be properly disclosed; the sources and amounts of compensation shall also be properly disclosed.

Substantial use of university facilities means extensive unreimbursed use of major university laboratory, studio or computational facilities, or human resources. The use of these facilities must be important to the creation of the intellectual property; merely incidental use of a facility does not constitute substantial use, nor does extensive use of a facility commonly available to all faculty or professional staff (such as libraries and offices), nor does extensive use of a specialized facility for routine tasks. Use will be considered "extensive" and facilities will be considered "major" if similar use of similar facilities would cost the creator more than \$5000 (five thousand dollars) in constant 1984 dollars if purchased or leased in the public market. Creators wishing to directly reimburse the university for the use of its facilities must make arrangements to do so before the level of facilities usage for a particular intellectual property becomes substantial. (This provision is not intended to override any other department or university policy concerning reimbursement for facilities usage.)

In general:

In any given year the equivalent figure for a particular amount of money in constant 1984 dollars will be obtained by multiplying that amount of money by the ratio of the most recent quarterly Disposable Personal Income Deflator divided by the average monthly Disposable Personal Income Deflator for the year 1984.

As used in this policy, the masculine gender includes the feminine gender, singular or plural, wherever appropriate.

3. Policy Provisions

This section states the policies concerning ownership of intellectual property created at the university. In order of precedence, ownership of intellectual property shall be as follows:

3-1. Externally Sponsored Work

Ownership Provisions: Intellectual property created as a result of work conducted under an agreement between an external sponsor and the university that specifies the ownership of such intellectual property shall be owned as specified in said agreement. If the university declares itself to be a sponsor, but does not declare itself to be the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by an externally sponsored contract of the intellectual property provisions of that contract in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on externally sponsored projects. A summary of external sponsorship agreements limiting the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by external sponsorship agreements, the creator is entitled to receive from the university 50% (fifty percent) of the net proceeds to the university resulting from his intellectual property.

3-2. Internally Sponsored Work

Ownership Provisions: When the university provides funds or facilities for a particular project to the extent of substantial use, it may also choose to designate itself as sponsor of that work. The university may declare itself the owner of intellectual property resulting from said work. In such cases the university must specify in advance the disposition of any intellectual property rights arising from the project. If the university declares itself to be a sponsor, but does not declare itself the owner of the intellectual property, ownership shall be determined in accordance with 3-6-4 below.

Procedural Provisions: It is the responsibility of the Office of Sponsored Research of the university to inform each person whose intellectual property rights are limited by internally sponsored work of the intellectual property ownership rights specified by the university as to that work in advance of the beginning of work thereon. Such notice is to be in writing and the university may require written acknowledgment of such provisions by any person working on internally sponsored projects. A summary of work for which university sponsorship limits the intellectual property rights of potential creators will be maintained by the Office of Sponsored Research and will be available to the general university community.

If the university fails to notify a creator, effectively and in advance, of limitations imposed on his intellectual property rights by internal university sponsorship, the creator is entitled to receive from the university 50% (fifty

percent) of the net proceeds to the university resulting from his intellectual property.

3-3. Individual Agreements

Ownership Provisions: Intellectual property which is the subject of a specific agreement between the university and the creator(s) thereof shall be owned as provided in said agreement. Such agreements by the university and the faculty are encouraged.

Procedural Provisions: Except where limited by external sponsorship agreements, creators and the university may negotiate individual agreements to govern ownership of intellectual property regardless of the applicability of any other provision hereof.

3-4. Intellectual Property Created Within Scope of Employment

Ownership Provisions: Intellectual property created by university employees who were employed specifically to produce a particular intellectual property shall be owned by the university if said intellectual property was created within the normal scope of their employment. Faculty are presumed not to be hired to produce a particular intellectual property. On the other hand, computer programs written on the job by staff computer programmers would fall under this provision.

3-5. Public Dedication

Ownership Provisions: Except when limited by sub-parts 3-1, 3-2, 3-3 or 3-4 above, the creator of any intellectual property may choose to place his or her creation in the public domain. In such cases both the creator and the university waive all ownership rights to said property.

Procedural Provisions: Creators wishing to place their intellectual property in the public domain are responsible for ascertaining that the right to public dedication of that intellectual property is not limited by any external agreement, university sponsorship arrangement or terms of employment as described in Provisions 3-1, 3-2 or 3-3. The university provost will provide such a determination in writing upon request by the creator. It is also the creator's responsibility to ensure that disclosure does not include valuable intellectual property owned by others. (This provision does not release the university from its general obligation to notify creators of limitations to intellectual property rights specified in Provisions 3-1 and 3-2.)

To facilitate the actual transfer of knowledge of the intellectual property to the public at large, the creator shall provide the university with a complete description and documentation of the property placed in the public domain, specifically including a copy of the property in the case of printed material, and complete machine-readable source code in the case of software. All such material provided to the university will be placed in the University Library and made available to the public at large. The university will take appropriate action on a regular basis to publicize summary descriptions of intellectual property recently placed in the public domain. The university will also provide any member of the general public copies of such material on a cost-recovery basis.

The provisions of this section do not apply to the normal scholarly or creative publication processes unless the creator intends to waive all proprietary rights to the publication.

3-6. In General

Unless governed by sub-parts 3-1, 3-2, 3-3, 3-4 or 3-5 above, ownership of intellectual property created at the university shall be determined as follows:

3-6-1. Traditional Rights Retained

Ownership Provisions: In keeping with academic traditions at the university, the creator retains all rights to the following types of intellectual property, without limitation: books (including textbooks), educational course-ware, articles, non-fiction, novels, poems, musical works, dramatic works including any accompanying music, panto-mimes and choreographic works, pictorial, graphic and sculptural works, motion pictures and other similar audio-visual works, and sound recordings, regardless of the level of use of university facilities. This provision does not include computer software (other than educational course-ware) or data bases.

Procedural Provisions: The types of intellectual property listed in the preceding paragraph share the attribute that they display information or visual or auditory appearances which are fully revealed to the purchaser or consumer. Thus, for example, source code listings would also be considered within this category. On the other hand, most computer software and data bases do not share this attribute; they are characterized by their capacity to perform tasks. Because of their utilitarian nature, ownership rights with respect thereto are governed by 3-6-3 or 3-6-4. Educational course-ware is included in this provision in all cases because of its role in furthering the primary educational mission of the university.

This provision applies regardless of any university sponsorship of the work, and it may be modified only by a specific prior agreement between the creator and the university. The use of university-owned computers and other facilities in the preparation of books and similar works does not alter this provision, though other university policies may limit such use or require reimbursement to the university. Similarly, the use of externally sponsored resources does not alter this provision, unless the creator is effectively notified in advance of such limitations to his rights in accordance with 3-1.

3-6-2. No Substantial Use of University

Facilities Ownership Provisions: The creator owns all intellectual property created without substantial use of university facilities, including intellectual property rights in computer software and data bases.

3-6-3. Substantial Use of University Facilities - No External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities, but not directly arising from externally sponsored work, or from work for which the university has declared itself as sponsor, shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-3-1. Development by Creator

Ownership Provisions: The creator originally owns intellectual property created with substantial use of university facilities but no external or internal sponsorship, and retains said ownership by commercial development of said property subject to the following:

(i) the university shall receive 15% (fifteen percent) of the net proceeds to the creator above \$25,000 (twenty-five thousand dollars) in constant 1984 dollars from all sources (in the case of patents and copyrights, this provision shall be limited to the life of the patent or copyright), and

(ii) the university shall receive a perpetual, non-exclusive, non-transferable, royalty free license to use said intellectual property. In the case of software, this license includes access by specified university personnel to the source listings, and the university shall require each person to whom a disclosure is made to execute in advance a binding confidentiality agreement in favor of and enforce-able by the creator. If the intellectual property is created solely by a student or students, the creator is exempt from the obligation to pay to the university a fraction of his net proceeds, but not from the provision of this paragraph for a non-exclusive license to the university.

Procedural Provisions: If the creator develops an intellectual property that is covered by this provision, he must make full and fair disclosure to the university of all such sources of compensation relating to that intellectual property.

3-6-3-2. Development by the University

Ownership Provisions: When intellectual property is created with substantial use of university facilities, but not directly arising from sponsored research, the creator will originally retain the rights to the property, provided that he desires to commercially develop the property himself or to make it available to the public. If, however, the creator elects not to commercially develop same or fails to show diligence in pursuing such development, then the ownership rights to that property may be acquired by the university. Intellectual property acquired by the university in this fashion will be treated as in 3-6-4-1 below.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required under Section 4-1, or at any time thereafter, the university may request that the creator decide whether he will develop the intellectual property or will grant the rights to the university, and execute documents to pass on the title. Such a decision must be made within one year of the request or the creator will automatically lose his rights in favor of the university.

3-6-4. Substantial Use of University Facilities - External or Internal Sponsorship

Ownership of intellectual property created with substantial use of university facilities and directly arising from work sponsored under an agreement between an external sponsor and the university, or from work for which the university has declared itself a sponsor, but for which neither the external sponsor nor the university have specified the ownership of resulting intellectual property shall be determined as set forth hereinafter depending on whether the creator or the university develops said property.

3-6-4-1. Development by University

Ownership Provisions: The university originally owns intellectual property created with substantial use of university facilities provided by an external agreement or internal university sponsorship and retains said ownership by commercial development of said property, subject to the following: in all cases, the creator shall receive 50% (fifty percent) of the net proceeds to the university.

Procedural Provisions: When an intellectual property is created with substantial use of university resources provided by an external research contract or a specific university sponsorship agreement, and when that contract or agreement either does not specify the disposition of the intellectual property rights arising from that sponsorship, or it permits the university and/or creator to retain or acquire such intellectual property rights, the university will originally retain the rights to such intellectual property.

3-6-4-2. Development by Creator

Ownership Provisions: When intellectual property is created with substantial use of university facilities provided by external or internal sponsorship, the university will originally retain the rights to the property, provided that it desires to commercially develop the property or to make it available to the public. If, however, the university elects not to commercially develop same or fails to show diligence in such development, the ownership rights to that property may be acquired by the creator. Intellectual property acquired by the creator in this fashion will be treated as in 3-6-3-1 above. This assignment of rights to the creator may be prohibited by the terms of an external sponsorship agreement with the university or by an internal university sponsorship declaration, but in such cases the creator must be notified in advance, as in Provisions 3-1 and 3-2.

Procedural Provisions: At the time the intellectual property is disclosed to the university's provost as required by Section 4-1, or at any time thereafter, the creator may request that the university decide whether it will commercially develop the intellectual property or execute an assignment of the intellectual property rights to the creator. Such a decision must be made within 120 (one hundred twenty) days of the request or the university automatically waives its rights in favor of the creator, and it must execute an assignment of these rights to the creator.

3-6-5. Consulting Agreements

Ownership Provisions: Work done by individuals as consultants to outside firms is presumed not to involve unreimbursed substantial use of university facilities, and the rights to intellectual property created under consulting agreements are retained by the outside firms or the individual as specified by the terms of the consulting agreement and the terms of Provision 3-6-2 above.

Procedural Provisions: Under university policy consulting work must not make substantial unreimbursed use of university facilities except by explicit prior agreement. Any member of the university community who is engaged in consulting work or in business is responsible for ensuring that provisions in his agreements are not in conflict with this policy of the university or with the university's commitments. The university's Innovation Transfer Office will, upon request, provide assistance in this respect. The university's rights and the individual's obligations to the university are in no way abrogated or limited by the terms of such agreements. Each creator of intellectual property should make his obligations to the university clear to those with whom he makes such agreements and should ensure that they are provided with a current statement of the university's intellectual property policy. Appropriate sample contract wording to cover various possible external consulting arrangements shall be available from the university provost.

4. General Procedures

4-1.

The creator of any intellectual property that is or might be owned by the university under this policy is required to make reasonably prompt written disclosure of the work to the university's provost, and to execute any document deemed necessary to perfect legal rights in the university and enable the university to file patent applications and applications for copyright registration when appropriate. This disclosure to the provost should be made at the time when legal protection for the creation is contemplated, and it must be made before the intellectual property is sold, used for profit, or disclosed to the public. Whenever legal protection for intellectual property is anticipated all persons engaged in such creative activity are encouraged to keep regular notebooks and records.

4-2.

Whenever the university undertakes commercial development it shall do so, if possible, in a fashion that provides for the widest possible dissemination, avoiding suppression of inventions from which the public might otherwise benefit, providing for non-exclusive licensing at reasonable royalties, and giving consideration to more favorable or royalty-free licensing to non-profit charitable institutions, minority businesses or enterprises in developing countries.

4-3.

The university's share of any proceeds under this policy will be used to reimburse the university for its expenses for commercial development of

intellectual property. Any additional return to the university will be used to further the academic purposes of all the disciplines of the entire university.

5. Resolution of Disputes

This policy constitutes an understanding which is binding on the university and on the faculty, staff, and students upon whom it is effective according to the terms of Section 6 below, as a condition for participating in research programs at the university or for the use of university funds or facilities.

Any question of interpretation or claim arising out of or relating to this policy, or dispute as to ownership rights of intellectual property under this policy, will be settled by the following procedure:

- The issue must first be submitted to the university's Intellectual Property Adjudication Committee in the form of a letter setting forth the grievance or issue to be resolved. The committee will review the matter and then advise the parties of its decision within 60 days of submission of the letter.
- If any of the parties to the dispute is not satisfied with the committee's decision, the party may seek binding arbitration in Pittsburgh, Pennsylvania and in accordance with the Rules of the American Arbitration Association then in effect. Judgment upon the award rendered by the arbitrator(s) may be entered in any court having jurisdiction thereof. The arbitrator(s) will give some weight to the decision of the Intellectual Property Adjudication Committee in reaching a decision. The losing party of the arbitration hearing will pay for all costs of the arbitration unless the arbitrator(s) specifies otherwise.

The Intellectual Property Adjudication Committee will consist of a chair who is a member of the tenured faculty, four other members of the faculty, and four other members representing, respectively, the university administration, the technical staff, and the graduate and undergraduate student bodies. Initially, half of the members of the committee (including the chair) will be appointed for two-year terms of office, and the remaining half will be appointed for a one-year term. After one year new members of the committee will be appointed for two-year terms of office. The chair will be appointed by the chair of the Faculty Senate, with the advice and consent of the Faculty Senate Executive Committee, and the remaining eight members of the committee will be appointed by the president of the university or his designee. At all times at least one of the faculty members will have had significant practical experience with intellectual property development and exploitation. The faculty members appointed by the president of the university will be selected from a list of nominees prepared by the Faculty Senate or its designated committee and nominees with experience in intellectual property development will be identified as such by the Faculty Senate. The staff representative will be selected from a list of nominees prepared by Staff Council, and the administration representative will be named directly by the president of the university or his designee. The graduate student representative will be selected from a list of nominees prepared by the Graduate Student Organization. The undergraduate representative will be chosen from a list of nominees prepared by the Student Senate. The committee will use the guidelines set forth in this policy to decide upon a fair resolution of any dispute.

If possible, the committee will also provide on request informal advisory opinions to creators and the university indicating how it is likely to interpret the provisions of this policy as it applies to special cases.

6. Effective Date of Policy

This policy will become effective August 27, 1985. Once effective this policy will be binding on new faculty, administration, and staff when hired, and on graduate and undergraduate students when admitted. Current faculty and staff will also become bound by this policy when they sign new employment contracts as the result of the renewal of limited-term appointments or promotion. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Unless the creator and the university agree to a different arrangement, intellectual property that is already partially developed at the time this policy becomes effective will be treated according to the provisions of the patent policy by which the University creator is currently bound. Similarly, members of the university working under contracts signed before the effective date of this policy who do not choose to accept this policy will remain bound by the patent policies that already apply to them. With respect to intellectual property developed during the course of employment at the university, this policy shall continue to be binding on any person whose relationship with the university becomes terminated. The university should take all administrative steps necessary to ensure that employees and students sign, upon initial employment, registration or at other appropriate times, forms that indicate their acceptance of this policy.

7. Amendments of the Policy

Amendments of this policy may be proposed by the Faculty Senate, Staff Council or university administration. Proposed amendments must be approved by a two-thirds majority of votes in the Faculty Senate and subsequently approved by a simple majority of votes cast in a referendum administered by the Faculty Senate that is open to all members of the faculty as defined by this policy and to the exempt staff, provided that this majority constitutes at least 25% (twenty-five percent) of those eligible to vote. This referendum must be preceded by an opportunity for public discussion open to all interested faculty, administration, staff and students. Amendments that are supported by the faculty and staff must then be approved by the president of the university and adopted by the university trustees. Once adopted, amendments will become binding on new faculty, administration, and staff when hired, on existing faculty and staff when they sign new employment contracts, and on graduate and undergraduate students when admitted. Other university personnel, including tenured faculty, and current staff and students may choose to become bound by this policy for future and pending intellectual property by voluntary written consent. Intellectual property that is already developed or under development at the time that an amendment to the policy is ratified will not be bound by the terms of the amendment without the voluntary written consent of both the creator and the university.

Footnote:

¹ This document presumes the existence of a university office to facilitate technology transfer. Such an office would serve as a clearinghouse for contacts with outside partners, would perform patent and copyright tasks, and would develop an effective marketing capability.

Policy on Student Privacy Rights

www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html
(<https://www.cmu.edu/policies/student-and-student-life/privacy-rights-students.html>)

Policy Statement

Under the Family Educational Rights and Privacy Act (FERPA), you have the right to:

- inspect and review your education records;
- request an amendment to your education records if you believe they are inaccurate or misleading;
- request a hearing if your request for an amendment is not resolved to your satisfaction;
- consent to disclosure of personally identifiable information from your education records, except to the extent that FERPA authorizes disclosure without your consent; and
- file a complaint with the U.S. Department of Education Family Policy Compliance Office if you believe your rights under FERPA have been violated.

1. Inspection

What are education records?

Education records are records maintained by the university that are directly related to students. These include biographic and demographic data, application materials, course schedules, grades and work-study records. The term does not include:

- information contained in the private files of instructors and administrators, used only as a personal memory aid and not accessible or revealed to any other person except a temporary substitute for the maker of the record;
- University Police records;
- employment records other than work-study records;
- medical and psychological records used solely for treatment purposes;
- records that only contain information about individuals after they have left the university; and
- any other records that do not meet the above definition of education records.

How do I inspect my education records?

- Complete an Education Inspection and Review Request Form (<http://www.cmu.edu/hub/registration/docs/review-record.pdf>) [PDF] (<https://www.cmu.edu/hub/registration/docs/review-record.pdf>)

www.cmu.edu/hub/docs/review-record.pdf) and return it to The HUB in order to notify the University Registrar's Office.

- The custodian of the education record you wish to inspect will contact you to arrange a mutually convenient time for inspection, not more than 45 days after your request. The custodian or designee will be present during your inspection.
- You will not be permitted to review financial information, including your parents' financial information, or confidential letters of recommendation, if you have waived your right to inspect such letters.
- You can get copies of your education records from the office where they are kept for 25 cents per page, prepaid.

2. Amendment

How do I amend my educational records?

- Send a written, signed request for amendment to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. Your request should specify the record you want to have amended and the reason for amendment.
- The university will reply to you no later than 45 days after your request. If the university does not agree to amend the record, you have a right to a hearing on the issue.

3. Hearing

How do I request a hearing?

- Send a written, signed request for a hearing to the University Registrar, Carnegie Mellon University, A19 Warner Hall, Pittsburgh, PA 15213. The university will schedule a hearing no later than 45 days after your request.
- A university officer appointed by the Associate Vice President & Director of Enrollment Services who is not affiliated with your enrolled college will conduct the hearing.
- You may bring others, including an attorney, to the hearing to assist or represent you. If your attorney will be present, you must notify the university ten days in advance of the hearing so that the university can arrange to have an attorney present too, if desired.
- The university will inform you of its decision, in writing, including a summary of the evidence presented and the reasons for its decision, no later than 45 days after the hearing.
- If the university decides not to amend the record, you have a right to add a statement to the record that explains your side of the story.

4. Disclosure

Carnegie Mellon generally will not disclose personally identifiable information from your education records without your consent except for directory information and other exceptions specified by law.

What is directory information?

Directory information is personally identifiable information of a general nature that may be disclosed without your consent, unless you specifically request the university not to do so. It is used for purposes such as compiling campus directories.

If you do not want your directory information to be disclosed, you must notify the University Registrar's Office in writing within the first 15 days of the semester.

Notifying the University Registrar's Office covers only the disclosure of centralized records. Members of individual organizations such as fraternities, sororities, athletics, etc. must also notify those organizations to restrict the disclosure of directory information.

Carnegie Mellon has defined directory information as the following:

- your full name
- local/campus address and local/campus telephone number
- email User ID (Andrew ID) and address
 - Please note: Andrew User IDs cannot be completely suppressed from our electronic systems. While it may be possible to suppress the association of an individual's name with their user id, doing so may adversely impact the delivery of electronic mail or other electronic services.
- major, department, college

- class status (freshman, sophomore, junior, senior, undergraduate or graduate)
- dates of attendance (semester begin and end dates)
- enrollment status (full, half, or part time)
- date(s) of graduation
- degree(s) awarded
- sorority or fraternity affiliation

For students participating in intercollegiate athletics, directory information also includes:

- height, weight
- sport of participation

What are the other exceptions?

Under FERPA, Carnegie Mellon may release personally identifiable information from your education records without your prior consent to the following individuals or organizations:

- school officials with legitimate educational interests ("School officials" are Carnegie Mellon employees in administrative, supervisory, academic or support staff positions; Carnegie Mellon trustees; individuals and companies with whom the university has contracted, such as attorneys, auditors, or collection agencies; and individuals assisting school officials in performing their tasks. School officials have a "legitimate educational interest" if they need to review an education record in order to fulfill their professional responsibilities.);
- certain federal officials in connection with federal program requirements;
- organizations involved in awarding financial aid;
- state and local officials who are legally entitled to the information;
- testing agencies such as the Educational Testing Service, for the purpose of developing, validating, researching and administering tests;
- accrediting agencies, in connection with their accrediting functions;
- parents of dependent students (as defined in section 152 of the Internal Revenue Service Code);
- individuals or organizations in order to comply with a judicial order or subpoena (after making a reasonable effort to notify the student in advance of compliance so that the student can take protective action, except in cases where the university is legally required not to disclose the existence of the subpoena);
- appropriate parties in a health or safety emergency, if necessary to protect the health or safety of the student or other individuals;
- officials of another school in which the student seeks or intends to enroll;
- victims of violent crimes or non-forcible sexual offenses (the results of final student disciplinary proceedings);
- parents or legal guardians of students under 21 years of age (information regarding violations of university drug and alcohol policies);
- courts (records relevant to legal actions initiated by students, parents or the university); and
- individuals or organizations in order to comply with federal laws concerning sex offenders and other individuals required to register under section 170101 of the Violent Crime Control and Law Enforcement Act of 1994.

5. Complaints

If you believe the university has not complied with FERPA, you can file a complaint with the:

Family Policy Compliance Office, Department of Education, 400 Maryland Avenue, S.W. Washington, DC 20202-4605

Note: Your Carnegie Mellon GUID (global user identification) number is also designated as directory information under FERPA, but does not contain personally identifiable information and therefore cannot be used by itself to determine your identity or to access your records.

Policy on Restricted Research

www.cmu.edu/policies/research/restricted-research.html (<https://www.cmu.edu/policies/research/restricted-research.html>)

Universities have two primary purposes: to create knowledge and to disseminate knowledge. Carnegie Mellon University recognizes the importance of open intellectual communication within a research group, within the university, and within the larger community outside. Ideally, all units of the university would disseminate the results of research as quickly and as widely as possible. Some members or units of the university, however, desire to do research that may be difficult or impossible without restrictions or without access to classified or proprietary materials.

There exists, therefore, a tension between the university's goal of disseminating knowledge freely and the desire on the part of some of its members to conduct restricted research on important problems. The university intends to guarantee the academic freedom of all faculty members to do research in their own manner on topics of their own choosing, provided that such research is consistent with the overall purposes of the university.

This policy seeks to resolve the tension between the desire to participate in restricted research and the desire to maintain the open atmosphere of the university by confining restricted research to semi-autonomous units, which are not associated with any academic departments. It thereby establishes the principle that restricted research is inappropriate at Carnegie Mellon University except in the semi-autonomous units.

This policy does not attempt to anticipate all possible concerns about restricted research. In some cases, decisions will need to be made about particular research projects to which the application of particular policy guidelines are not clear. In choosing to accept or decline such projects, the university will weigh the potential of a project for generating and disseminating new knowledge for the benefit of society, against the project's potential for adversely affecting the climate for research conducted in a free and open environment. While this policy sets no explicit limits on the extent of classified research permitted in the semi-autonomous units, it is not the intent of the policy to encourage any unit of the university to engage in classified research as a primary ongoing activity. Indeed, it is expected that classified projects will never represent more than a small fraction of the total research effort in any unit.

Definitions

Research: all projects and investigations involving the creation of new knowledge of a theoretical or practical nature. The term "research" as used here encompasses both "research" and "development" as they are commonly defined.

Classified research: research, the free dissemination of the results of which is deemed to jeopardize national security. The federal government controls access to the environment in which such research is performed, restricts discussions about the work in progress to individuals with clearance and a "need to know," and limits publication of research, results or access to data needed to verify results, for a specified period of time.

Proprietary research: research that results in intellectual property that is owned by entities other than Carnegie Mellon University. Such entities may wish to market products derived from inventions or ideas that are developed at the university. They might, therefore, desire to fund projects which restrict access to data and to discussions about work in progress to individuals with a "need to know," and to seek, for a specified period of time, a delay in publication of research results or data needed to verify results. Such entities may also provide access to proprietary material, which researchers must agree not to include in publications.

Publication: oral or written dissemination.

Restricted research: includes all classified research, and any proprietary or other research that requires more than a six month delay in publication of the research results.

Semi-autonomous units: units of the university specifically so designated by the president, after consultation with the URC and the Faculty Senate, currently the Mellon Institute and the Software Engineering Institute.

Non-autonomous units: all university entities other than semi-autonomous units.

Restricted Research in Non-Autonomous Units

It is the policy of Carnegie Mellon that restricted research is inappropriate and, therefore, not permitted within its non-autonomous units.

It is also the policy of Carnegie Mellon not to permit involvement of students in projects which carry restrictions that may impede their progress toward a degree. Therefore, students should not be involved in contracts that require

the delay of a student's publication of research results when such results are intended for use in obtaining academic credit, except that a sponsor may require a delay of thirty days for review of publications for removal of proprietary information that was provided by the sponsor for the conduct of the research.

Proprietary research is allowed within non-autonomous units provided it is subject to limitations (excluding students' publications as noted above) no more stringent than the following:

- A sponsor may request a delay of up to six months in publication so that steps may be taken to secure intellectual property rights to inventions or ideas developed under the contract.
- A sponsor may require a delay of thirty days for review of publications for removal of proprietary information which was provided for the conduct of the research.

Considerations for faculty/researchers:

The university recognizes that problems arise in both restricted research and research that is not itself restricted but that involves access to classified or propriety information or materials (hereinafter, restricted materials). Researchers may also have access to restricted materials when serving as consultants. Access to restricted materials gives rise to concerns about limitations on researchers' freedom to communicate. In such instances, researchers must exercise consider-able judgment to conduct their research in an open environment while protecting the restricted materials to which they have access. Researchers must also be aware that the university will judge their performance as researchers through their publications or through other scholarly products that arise from their research. Research that is restricted in dissemination, or not available for public review, cannot be considered in promotion or reappointment decisions or in evaluations of academic performance of any kind.

Considerations for faculty/researchers:

There are important concerns about the involvement of students in restricted research. It is necessary for students to publish their work in order to obtain degrees, course credit and professional recognition. Students rely to a large degree on their faculty advisor's judgment for guidance and advice. Research that is restricted in dissemination, or not available for public review, cannot be used for academic credit. Thus, before working on such research, a student must be notified in writing that work on this research may not be used for academic credit.

Restricted Research in Semi-Autonomous Units

The semi-autonomous units associated with Carnegie Mellon may conduct restricted research.

Faculty members may conduct restricted research in or in cooperation with semi-autonomous units only on a consulting basis or by means of a formal, internal leave of absence from their non-autonomous units.

Work that is restricted in any way may not be used for academic evaluations until it is released for publication, and then only with respect to future academic actions.

Students may occasionally be employed by the semi-autonomous units, provided that such employment does not interfere substantially with progress toward a degree. However, they must be made aware that work that is restricted cannot be used for academic credit. Work that was restricted and is later released for dissemination and review can be applied toward future academic credit. Students should be discouraged from working on restricted research in which dissemination may be delayed indefinitely.

Guidelines for all Units

Work by students on restricted research projects shall not be made a condition for admission or financial aid.

The principal investigator is responsible for informing all members of a project (faculty, staff and students) of any restrictions imposed on the dissemination of information related to the research. This must be done prior to the start of the project or prior to an individual joining an existing project.

Restrictions on access to university facilities due to the conduct of restricted research must be kept to a minimum. Access to and movement through the facilities in which restricted research is conducted must be consistent with standard university procedures.

The Provost's Office is responsible for obtaining signed documents from principal investigators on restricted research projects attesting that they are aware of all restrictions imposed on the research and that they have informed all participants of these restrictions.

The Office of Sponsored Research shall review all proposals and contracts prior to approval for conformity with these guidelines. Any that do not meet these guidelines will be referred to the University Research Council (URC) for review and recommendation of appropriate action to the provost.

To maintain a balance with the university's goals of broad dissemination of knowledge, the URC will conduct an annual review of all restricted research being conducted at the university. This review will be made based on a listing of all contracts that involve restricted research. This listing shall include the title and sponsor(s) of the research, name(s) of principal investigator(s), and the amount of funding of each contract.

The university community will be informed annually, through the URC's written report to the Faculty Senate and Student Senate, of the nature and overall impact of restricted research at Carnegie Mellon.

Existing sponsored research projects shall be allowed to continue under the terms of their present contract. However, renewal contracts must conform with this policy.

Student Activities Fee

www.cmu.edu/policies/student-and-student-life/activities-fee.html (<https://www.cmu.edu/policies/student-and-student-life/activities-fee.html>)

By action of the Board of Trustees, a required Student Activities Fee in addition to tuition is charged to all under-graduate students and graduate students who enroll for 19 units or more. Student Government is responsible for administering the fee and for using it only for the support of projects under the following guidelines:

1. Activities and facilities which can be described as meeting the reasonably predictable social, cultural, recreational, or welfare needs of college students.
2. Publications which can reasonably be presumed to serve the needs of the student community for communication, expressions of opinion, and the conduct of their business.
3. Such enterprises of an entrepreneurial nature undertaken by the student body as can reasonably be expected to serve as an instrument for meeting the needs described above.

All functions and services provided by the fees described above must be in accordance with Carnegie Mellon's policy of non-discrimination. In addition, no use of such fees may be intended to violate or circumvent the policies of the university or the laws of the land.

Final responsibility for establishing the amount of any required fee rests with the Board of Trustees, which will consider changes only upon requests of the Student Government and the officers of the university.

Note: Historically, the Student Government has dedicated a specific portion of graduate students' activities fees to the Graduate Student Assembly to be used at their discretion.

Policy on Temporary Emergency Closing of the University

www.cmu.edu/policies/safety-and-security/emergency-closing.html (<https://www.cmu.edu/policies/safety-and-security/emergency-closing.html>)

Policy Statement

Carnegie Mellon University has an important commitment to students, parents, sponsors, benefactors and the community. Accordingly, the university will make every attempt to operate normally during severe weather or other emergencies. This includes holding classes, conducting research programs, and operating facilities and services. The university will attempt to operate normally unless such operation represents a clear danger to students, staff or faculty.

There may be occasions when the university community is served best by suspending normal operations. In that event, only the president (or the president's designated representative) has the authority to close the university and to specify those persons or group of persons who are free to leave or refrain from coming to campus. Staff members who provide primary services, including certain members of Physical Plant, Dining Services and Security, may be asked to work.

Standard Operations

Unless the president announces that the university is closed, everyone is expected to be at work as usual. When the university is in session, faculty members are expected to meet their scheduled classes and other

obligations. If a faculty member is unable to meet a scheduled class, he or she should notify the department office and arrange either for a qualified substitute or for a future make-up session.

If the university is open but a staff member is unable to come to work because of severe weather or other emergency, he or she should notify the supervisor as soon as possible. Staff members will be expected to make up lost time or use Paid Time Off (PTO), consistent with regular operating protocols.

Announcement of Closing

As soon as the president or designee determines that the university must be closed, University Relations will alert local radio and television stations. Also, announcements of closings will be posted on the Carnegie Mellon electronic board official.cmu-news.

Contact

Questions concerning this policy or its intent should be directed to the Office of the President at 412-268-2200.

Student Leaves & Returns

Student Leave Policy

www.cmu.edu/policies/student-and-student-life/student-leave.html (<https://www.cmu.edu/policies/student-and-student-life/student-leave.html>)

Students must sometimes interrupt their studies for a variety of reasons (financial, academic or personal). Students choosing to take a leave of absence must first contact their department advisor to discuss their plans while on leave to work out any conditions that may be necessary for a smooth return to Carnegie Mellon.

A student may leave Carnegie Mellon by either withdrawing from the university (this means leaving the university with no intention of returning) or by taking a leave of absence (this means leaving the university temporarily, with the firm and stated intention of returning).

A Leave of Absence Form must be completed by all students requesting a leave of absence. A Withdrawal Form must be completed by all students who are withdrawing. Notifying instructors or no longer attending classes does not complete the process. Forms and related documentation are available on The HUB website (<https://www.cmu.edu/hub/registrar/leaves-and-returns/>). Not completing the leave form results in tuition being charged to the midpoint of the semester or the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Students are required to fill out all information on the form, including all comment sections relating to reasons for their leave of absence. After completion of the form, students must take it to their home department and dean's office for appropriate signatures. The process of taking a leave will not be complete until all necessary signatures are on the leave form. Under certain circumstances, students may also need the Dean of Student Affairs to sign off on the leave form. International students who are here on a F1 or J1 visa must consult the Office of International Education for information on possible visa implications prior to going on leave.

Students on leave are not permitted to live in university housing, attend classes or maintain employment as students at Carnegie Mellon while their leave is in effect.

Doctoral candidates in ABD (All But Dissertation) status who wish to take a leave of absence should refer to the Doctoral Student Status policy (<https://www.cmu.edu/policies/student-and-student-life/doctoral-student-status.html>).

Leaves during the academic semester will take effect as of the date signed by the student's dean. After the Leave of Absence or Withdrawal Form is received by the University Registrar's Office, it will be reviewed for the appropriate tuition refunds (see T (p. 14) Tuition Adjustment Policy (p. 14)) and grade implications. The recording of student courses and grades for taking a leave in a semester follows the deadlines for semester or mini courses, as follows:

- On or before the university deadline to drop classes with W (withdrawal) grades: all courses or grades are removed.
- After the university deadline to drop classes but before the last day of classes: W (withdrawal) grades will be assigned to all classes. (W grades apply to all undergraduate students, and graduate students in the Carnegie Institute of Technology, the Mellon College of Science or the Tepper School of Business.)
- After the last day of classes: Permanent grades assigned by the instructor will be recorded.

Student Return Policy

www.cmu.edu/policies/student-and-student-life/return-student.html (<https://www.cmu.edu/policies/student-and-student-life/return-student.html>)

Students on leave wishing to return to Carnegie Mellon to resume their degree studies may do so under several conditions. In order to be considered for return from leave (<https://www.cmu.edu/hub/registrar/leaves-and-returns/>), a student must first obtain an Application for Return form from The HUB or their academic department. This application requires information from the student regarding the intended semester of return, current address information and information about their leave. This application must be submitted to their home department at least one month prior to the beginning of the semester.

Undergraduates may return within their same academic department within two years. After two years, students returning in the same academic department are subject to space constraints and academic performance review. Graduate students must negotiate their return with their home department and must follow their department policy.

The Application for Return requires approval of the student's academic department and dean. If a student's department chooses to deny the student's Application for Return, the student may appeal to their dean. Any constraints governing the student's eligibility to return will be specified directly on the application by the academic department and/or dean's office or the Office of Student Affairs.

Students who have taken courses elsewhere must submit an official transcript and course descriptions with their Application for Return. Transfer credit approval is determined by the academic department based on course level, performance and appropriateness to the student's curriculum requirements. Credit transfer is subject to college-specific policy. Failure to submit the necessary documents at the time of return will result in denial of transfer credit.

The process of returning is not completed until all necessary signatures on the Return form are obtained by the student and until all outstanding bills are paid. The University Registrar's Office will then notify the appropriate university offices of the student's return.

Tuition Adjustment Policy

www.cmu.edu/policies/student-and-student-life/tuition-fees-adjustment.html (<https://www.cmu.edu/policies/student-and-student-life/tuition-fees-adjustment.html>)

Application

This policy applies to withdrawals and leaves of absence by all students (graduate, undergraduate, non-degree) for all semesters (Fall, Spring, Summer 1, Summer 2, Summer All).

Official Date of Withdrawal/Leave of Absence

For students who notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is the earliest of:

- the date the student began the withdrawal or leave of absence process;
- the date the student notified their home department;
- the date the student notified the associate dean of their college; or
- the date the student notified the Dean of Students.

For students who do not notify the university of their intent to withdraw or take a leave of absence, the official date of withdrawal or leave of absence is:

- the midpoint of the semester;
- the last date the student attended an academically-related activity such as an exam, tutorial or study group, or the last day a student turned in a class assignment.

Tuition Adjustment

Students who withdraw or take a leave of absence before completing 60% of the semester will be charged tuition based on the number of days completed within the semester. This includes calendar days, class and non-class days, from the first day of classes to the last day of final exams. Breaks that last five days or longer, including the preceding and subsequent weekends, are not counted. Thanksgiving and Spring Break are not counted. There is no tuition adjustment after 60% of the semester is completed. No tuition is charged to a student who is administratively withdrawn. See The

HUB website (<https://www.cmu.edu/sfs/tuition/adjustment/>) for the complete tuition assessment schedule for the current semester.

Housing, Dining Plan & Fee Adjustments

Housing charges are adjusted daily, beginning on check-in day and ending on the last day of final exams for the semester. Holiday breaks are included; however, the Winter Break period is not included.

Dining plan charges are adjusted per the bi-weekly period. PlaidCash is assessed based upon actual use.

There is no adjustment of the Transportation Fee, Technology Fee or Student Activity Fee.

Financial Aid Adjustment

Federal and institutional financial aid is adjusted on the same basis as tuition. A student earns 100% of their federal or institutional financial aid when 60% of the semester is completed.

State grants and non-federal outside scholarships are adjusted based upon the withdrawal policy of the agency awarding the funds.

Contact

Questions concerning this policy or its intent should be directed to The HUB at 412-268-8186.

Financial Aid Policy Statement

www.cmu.edu/policies/student-and-student-life/financial-aid-statement.html (<https://www.cmu.edu/policies/student-and-student-life/financial-aid-statement.html>)

University Academic Scholarship Renewals

Carnegie Mellon University awards academic scholarships as part of the first-year financial aid process. Each of these scholarships is renewable for four academic years of study (five for architecture) based upon the maintenance of a specific cumulative quality point average. The academic scholarship renewal criteria are included in the scholarship notification letter which is mailed to the student prior to the May 1 matriculation deadline.

Each scholarship recipient's cumulative quality point average is reviewed at the end of each academic year. If the student achieves the scholarship renewal criteria, then the scholarship is automatically renewed for the next academic year.

If the student does not meet the cumulative quality point average requirement for renewal, then they are given the opportunity to appeal. A merit scholarship appeal form and instructions are automatically sent to the student at the end of each academic year.

The student's completed appeal form is reviewed by Student Financial Services. Input from the Associate Dean of the student's college is also considered. The student is notified, in writing, of the decision. The decision may be to renew the scholarship for the entire academic year, renew the scholarship for one academic term, or to reject the appeal. If the appeal is rejected, a written explanation is provided to the student.

Undergraduate Tuition Exchange Programs

Carnegie Mellon University assesses the standard tuition charge for the undergraduate tuition exchange programs.

Since Carnegie Mellon assesses the tuition charge, the student can be considered for all forms of institutional, state, and federal aid for which the student may have eligibility with the exception of any student employment program.

Undergraduate Study Abroad Programs

Carnegie Mellon University does not assess the tuition charge for any of the Study Abroad Programs.

Since Carnegie Mellon does not assess the tuition charge, the student is not considered for any institutional grants and scholarships. However, Carnegie Mellon will consider any student participating in an approved Study Abroad Program for all state and federal student aid programs for which the student may have eligibility with the exception of any student employment program.

The U.S. Department of Education and Carnegie Mellon University define an approved Study Abroad Program as one which is part of a contractual agreement between Carnegie Mellon and the host institution. Additionally, courses taken in the Study Abroad Program must be accepted for transfer to Carnegie Mellon by the Dean of the student's college.

Undergraduate Sponsored Study Abroad Programs

Carnegie Mellon assesses full tuition charges and all applicable fees to students participating in an undergraduate sponsored study abroad program.

Undergraduate International Students

Documentation Eligibility (U.S. Citizenship or Eligible Non-citizen)

You must be a U.S. Citizen or permanent resident alien to receive federal student aid. If you are a U.S. Citizen, but were not born in the United States, valid documentation includes a copy of your passport or naturalization certificate.

If you are a U.S. permanent resident alien or refugee, acceptable forms of verification include a photocopy of both sides of your I-551 or I-551C card.

Undergraduate international students are ineligible to receive any federal or state student financial aid. Additionally, Carnegie Mellon does not award any institutional financial aid funds to undergraduate international students.

Undergraduate Course Meeting Policy

www.cmu.edu/policies/student-and-student-life/ug-course-meeting.html
(<https://www.cmu.edu/policies/student-and-student-life/ug-course-meeting.html>)

No undergraduate classes, exams, academic, or artistic activities (including: extra help session, rehearsals, ROTC drill, make-up exams, etc.) are scheduled on weekdays between 4:40 p.m. and 6:40 p.m. Extra class time beyond those regularly scheduled must take place either before 4:40 p.m. or after 6:40 p.m.

Undergraduate Course Meeting Procedure

This policy is not intended to reduce the rigor or vigor of the academic or artistic programs, but to ensure that students have a period in which they are free to carry on co-curricular activities and athletics. Scheduling classes, exams, or other academic and artistic activities makes it very difficult for the students to meet these commitments. Since we are all concerned about the quality of life at the university, this time must be held for the students.

In planning the academic course schedule, the University Registrar's Office will review all courses to ensure that no academic or artistic courses be scheduled in this period. In addition, any requests to schedule additional or makeup course meetings, review and/or study sessions, teaching assistant office hours, or other course-related meetings, must take place either before 4:40 p.m. or after 6:40 p.m. This includes meetings in all university spaces, not just within University Registrar's Office-controlled classrooms.

As with any policy, there must be a means of making exceptions. Any academic or artistic activities which you feel must be scheduled between 4:40 p.m. and 6:40 p.m. must be cleared with the University Registrar. These requests must be in writing either as a memo or through email. All requests must include the course relationship, intent for the requested meeting, and the reason why the meeting cannot be held either before 4:40 p.m. or after 6:40 p.m.

Any further clarification of this policy can be addressed to the Vice Provost for Education.

University Services

Carnegie Mellon University provides many services to students to help them thrive on and off campus, and in and out of the classroom. The university's service-oriented departments and offices focus on executing critical administrative functions to provide daily services to students, families, the campus community, and visitors. Listed below are some of the services offered by the university.

Academic Advising

University Statement on Academic Advising

Carnegie Mellon University commits to support excellence in academic advising. Even with the university's diverse offerings, a cohesive academic advising approach can directly impact the educational success of every undergraduate and graduate student. High quality advising rests upon (1) robust central resources, (2) discipline specific variations at the college- and program-levels, (3) skilled academic advisors of all types, and (4) engaged, committed students. By conceptualizing advising as an ecosystem, CMU creates an environment that fosters long-term outcomes that benefit students while studying at CMU as well as making a difference as lifelong alumni.

The Advising Ecosystem at CMU

Goals

The advising ecosystem centers attention on the growth and development of CMU students while they are enrolled and beyond. Excellent advising is as varied as our disciplines and students; yet, centralized standards, systems, and resources must connect seamlessly so that students make well-informed decisions. Advisors are supported in their work allowing for professional growth, intellectual satisfaction, and institutional recognition.

The ideal advising experience at CMU should reflect qualities of the academic environment: integrated, collaborative, innovative and data-driven. From guiding the transition into the university, movement through the curriculum, and exploration of careers or post-graduate studies, the advising ecosystem supports students in utilizing resources and setting and achieving their goals.

The CMU advising ecosystem seeks to facilitate:

- Goal setting and planning
- Leveraging support network
- Accessing resources
- Understanding policies
- Planning for career and post-graduation

advising practice, tools, and strategies

In order to realize our vision of excellent advising, CMU invests in an advising ecosystem that includes a host of resources and strategies designed to engage and facilitate students' academic and personal development.

- Adequate advising staffing and resources within each department/program
- Advisor training and professional development`
- Intentional focus on student success
- Collaboration to support student success
- Implement technology
- Contribute to career planning goals

student engagement in advising

Based on research at the national level and years of experience working with CMU students, the CMU advising ecosystem is designed to facilitate student behaviors that are proven to lead to success at the university. By engaging with the broad range of advising resources and student success strategies, students are expected to exhibit these behaviors indicating that they are on the path to successfully complete their degree requirements and attain personal development goals.

- Set goals and plan
- Engage the CMU support network
- Access resources
- Know and follow the rules
- Oriented towards the future

STUDENT outcomes

By engaging with the advising at CMU advising, students have opportunities and resources to exhibit the success behaviors outlined above. By conceptualizing advising as an ecosystem, CMU is creating an environment that fosters these long-term outcomes that benefit students both while they are students at CMU as well as lifelong alumni.

As a result of being advised at CMU, students are able to:

- maintain good academic standing in the university,
- feel a sense of belonging and inclusion within the university and their department,
- have individual and supportive relationships with their advisors and professors,
- maintain adequate progress toward completing their degree,
- find employment or further education directly related to their education plan or degree program after graduation; and
- use the skills and knowledge they have gained at Carnegie Mellon University to advance their professional and personal goals after leaving the university.

Computing Services

Stan Waddell, *Vice President for Information Technology & Chief Information Officer*

Location: Cyert Hall 285

Phone: 412-268-4357

it-help@cmu.edu

www.cmu.edu/computing (<http://www.cmu.edu/computing/>)

Computing Services maintains and supports computing resources for the campus community, including the campus wired and wireless networks, public printing, computer labs, email and software catalog.

Visit the Computing Services (<http://www.cmu.edu/computing/>) website to explore the services available to you, including how to:

- secure your devices
- connect to the network
- collaborate with your group
- access software
- manage your email
- use public printers and computer labs.

For help with these services, contact the Computing Services Help Center at 412-268-4357 (HELP) or it-help@cmu.edu.

Disability Resources & Equal Opportunity

Catherine Getchell, *Director of Disability Resources*

Location: Margaret Morrison Plaza, A30, 5136 Margaret Morrison St., Pittsburgh, PA 15213

Phone: 412-268-6121

access@andrew.cmu.edu

www.cmu.edu/disability-resources (<https://www.cmu.edu/disability-resources/students/>)

Disability Resources provides responsive and reasonable accommodations to students who self-identify as having a disability, including physical, sensory, cognitive and emotional disabilities. Through our office, the university can provide counsel, support services and accommodations to ensure that all students, regardless of ability, have equal access to the world-class education, campus programs and activities offered by CMU. We work to ensure that qualified individuals receive reasonable accommodations as guaranteed by the Americans with Disabilities Act (ADA) and Section 504 of the Rehabilitation Act of 1973.

Students are also welcome to discuss concerns about support for disabilities with members of the admission staff, housing office and/or health/psychological services. Upon enrollment, students with disabilities should contact the Office of Disability Resources to discuss their needs and to develop a Student Individual Accommodation Plan. Accommodations are made with the intent to maintain the academic integrity of each course and the academic program as a whole, while also meeting assessed needs.

Equal Opportunity / Affirmative Action Policy

Carnegie Mellon is committed to equal employment opportunity for all and to affirmative action. Diversity is a source of strength for Carnegie Mellon and affirmative action is one of the tools that we use to achieve and sustain diversity. All personnel actions are administered in accordance with the university's commitment to non-discrimination and in compliance with applicable federal, state and local laws, statutes, orders and regulations. View the University Policy on Equal Employment Opportunity / Affirmative Action (<https://www.cmu.edu/policies/administrative-and-governance/equal-opportunity-affirmative-action-ada.html>).

Honor Societies

Phi Beta Kappa Society

Carnegie Mellon shelters a chapter of the Phi Beta Kappa Society, sponsored by the three colleges (Dietrich College of Humanities and Social Sciences, Mellon College of Science, and the School of Computer Science) that comprise the University's "arts and sciences" equivalent. The chapter's name is "Upsilon of Pennsylvania," and was formally installed in April of 1995.

Founded in 1776 at the College of William and Mary in Williamsburg, Va., Phi Beta Kappa is the nation's oldest honorary society, with chapters at 276 of the foremost institutions of higher education across the country. Almost all members are elected by the chapters from among candidates for degrees in liberal arts and sciences, usually from the top 10% of the graduating class.

Membership in Phi Beta Kappa key has become a universally recognized mark of academic achievement in the liberal arts and sciences. The key's venerable pointing finger proclaims for all to see the wearer's commitment to Phi Beta Kappa's ancient principles (represented in the three stars) — friendship, morality and learning. The society's name is formed by the first letters of the phrase *Philosophia Biou Kybernetes*, Philosophy (wisdom) is the Guide of Life. In line with the conviction that the test of education lies not in what people know but in what they are, the objectives of humane learning encouraged by Phi Beta Kappa include not merely knowledge but also intellectual honesty and tolerance, a broad range of intellectual interests and understanding.

The Carnegie Mellon chapter is active in sponsoring visiting speakers, on-campus roundtables that focus on current issues, community service activities, scholarship opportunities, student research involvement, and the like.

The Honor Society of Phi Kappa Phi

The Honor Society of Phi Kappa Phi has been an important presence on campus since 1933. Phi Kappa Phi, a national honor society that began in 1897 at the University of Maine, takes its name from the initial letters of its adopted motto, *Philosophia Kratoito Photon*, "Let the love of wisdom rule humanity." Phi Kappa Phi recognizes and honors persons of good character who have excelled in scholarship, in all fields of study. Members are nominated by their department or their school or college and then invited to join the society.

To be eligible, seniors must be in the top ten (10) percent of their class and juniors in the upper seven and one-half (7.5) percent of their class at the time of invitation. Graduate students, alumni, faculty and staff are also eligible for nomination. The chapter inducts new members once a year, each spring, and provides information to its members on all sorts of opportunities, including study abroad, internships, and graduate fellowships, recognition and awards.

Office of Undergraduate Research and Scholar Development

Undergraduate Research

Richelle Bernazzoli, *Director of Undergraduate Research and Scholar Development*

Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213
Phone: 412-268-5702

Fax: 412-268-6159

Email: bernazz@andrew.cmu.edu
www.cmu.edu/uro/ (<http://www.cmu.edu/uro/>)

At Carnegie Mellon, undergraduates are building mobile robots, creating documentary films, investigating cultural trends, and developing new digital communication technology. These student researchers find themselves in the heart of the university intellectual community, where they discover the thrilling (and often messy) process of creating new knowledge.

We use a broad definition of research that includes appropriate activities in the arts and humanities, as well as the sciences and technical fields: "Research, scholarly, or artistic activities that lead to the production of new knowledge; to increased problem solving capabilities, including design and analysis; to original critical or historical theory and interpretation; or to the production of art or artistic performance."

The Office of Undergraduate Research and Scholar Development supports student research in every field of study. We give SURG grants (<https://www.cmu.edu/uro/research%20grants/SURG/#surg>) to cover research expenses, Summer Fellowships (<https://www.cmu.edu/uro/summer%20research%20fellowships/SURF/#surf>) for full-time summer research, and Presentation Awards (<https://www.cmu.edu/uro/PresAward/#pres>) to support students presenting at academic conferences. In May of each year, we hold our campus-wide celebration of undergraduate research, the Meeting of the Minds (<https://www.cmu.edu/uro/MoM/#MoM>).

How can we help?

- **Advising:** We meet with students to discuss how best to move forward on their interests and engage in undergraduate research at Carnegie Mellon
- **Workshops:** We offer writing workshops each semester to assist students in the proposal writing process
- **Individual Meetings:** We meet with students individually to review their proposals and make suggestions

National and International Fellowships and Scholarships

Location: Cyert Hall A64, 5000 Forbes Ave., Pittsburgh, PA 15213

Phone: 412-268-9987

Fax: 412-268-6159

Email: fso-general@andrew.cmu.edu

www.cmu.edu/ (<http://www.cmu.edu/uro/>)[fso](https://www.cmu.edu/fso/) (<https://www.cmu.edu/fso/>)

The Office of Undergraduate Research and Scholar Development works with current Carnegie Mellon undergraduate and graduate students, as well as alumni, in fulfilling their intellectual and professional goals by pursuing nationally competitive scholarships and fellowships. We promote awareness of external scholarship and fellowship opportunities, advising, writing support, overall management of the process, and interview preparation.

For information about fellowships and scholarships related to financial aid, please visit Student Financial Services (<https://www.cmu.edu/sfs/financial-aid/>) website.

What are fellowships and scholarships?

Fellowships and scholarships are competitive, merit-based monetary awards that support a wide range of purposeful activities. These include research, internships, projects, and study abroad.

Who is eligible?

Eligibility depends on the particular award. More detail is available in the descriptions and links to each award.

How do I get started?

Read through the award descriptions on our website (<https://www.cmu.edu/fso/>) and make a list of which you'd like to pursue. Then make an appointment (<https://cmu.joinhandshake.com/appointments/new/>) with a representative.

Student Academic Success Center

Renee Camerlengo, *Executive Director*

Location: Posner Hall, 1st and 2nd floors

Phone: 412-268-6823

www.cmu.edu/student-success (<https://www.cmu.edu/student-success/>)

The Student Academic Success Center focuses on creating spaces for students to engage in their coursework and approach to learning through many group and individual program options. The team supports student success by providing academic coaching, subject-specific tutoring, effective communication strategies, accommodations for students with disabilities, and language support for multilingual learners. They also engage with faculty and with staff to improve the coordination and professional development for academic advisors.

Teacher Certification

Carnegie Mellon offers a teacher certification program in the school of music but does not offer a degree in education or teacher certification program in other academic areas. Students can take relevant classes through several departments on campus to develop skills and knowledge that will help them to prepare for a career in K-12 education. There are several pathways to a teaching career and interested students can reach out to the Leonard Gelfand Center (<https://www.cmu.edu/gelfand/contact-us.html>) to discuss opportunities and programs that can be pursued.

University Libraries

Keith Webster, *Dean of University Libraries and Director of Emerging and Integrative Media Initiatives*

Location: Hunt Library, 4909 Frew St., Pittsburgh, PA 15213

Phone: 412-268-2444

www.library.cmu.edu (<http://www.library.cmu.edu>)

The University Libraries is an essential academic partner, whose services, expertise, and collections are at the heart of the work of CMU. The Libraries strengthen the work of the CMU academic community to ensure its transformative impact on our campus and beyond. Offering digital resources, research support, enhanced learning spaces – and so much more – Hunt, Sorrells, Mellon and CMU-Q libraries enrich the CMU student experience and benefit all members of the our community.

Build and Expand Digital Resources

The libraries create digital resources by scanning archival & rare collections; licensing specialized resources to support campus research; and purchasing perpetual access to online journals, electronic books and specialized web resources.

Showcase Research Excellence

The library provides digital infrastructure exposing faculty publications & research to be visible to the world. The Libraries contribute to author publication charges that enable current faculty research to appear in open access journals and monographs.

Enhance Learning Spaces

Learning in the library requires both individual and group focused learning environments as well as technology to maximize the learning experience. Technology enhancements range from flat screen displays to tools for using visualization software.

Online Access

From the Libraries' home page (www.library.cmu.edu (<http://www.library.cmu.edu/>)), students and eligible campus community members can access:

- CAMEO library catalog – Use CAMEO to find out where materials are located in libraries on campus. See whether items are checked out, on reserve, or available to be borrowed.
- My Library Account – Renew books, put books on hold, see a list of what you have checked out, see fines
- Course Reserves – Find required materials that your professors have reserved for classes to use
- Research Help – Learn about key resources in your subject area, including the CMU librarian who is a subject specialist for your school or college
- Ask a Librarian – Interactive reference service staffed by CMU librarians (chat, IM, email, phone, or in-person)
- AND MUCH MORE – Library collections, articles and databases, E-Journals A-Z, library catalogs

"Library Catalogs" link to online catalogs for the University of Pittsburgh Library System, The Carnegie Library of Pittsburgh, and other local libraries. We are partners with Pitt and The Carnegie; you can get library cards and borrow directly from these nearby libraries.

University Police

Aaron V. Lauth, *Chief*

Location: 300 South Craig Street, Room 199, Pittsburgh, PA 15213

campuspd@andrew.cmu.edu

www.cmu.edu/police (<http://www.cmu.edu/police/>)

The Carnegie Mellon University Police Department provides police services 24 hours a day, seven days a week, 365 days a year. Police officers are responsible for patrolling all university owned or leased property. In addition to patrol, officers will respond and investigate crimes and other emergencies that are in progress or have already occurred.

The success of the Patrol Unit is largely dependent on the eyes and ears of the community it serves. Immediate notification facilitates a rapid response. All emergencies on campus, including fire and medical, should be reported immediately to University Police. If you see suspicious activity or a crime in progress, call the University Police immediately by calling 412-268-2323.

Students are responsible for their personal property as well as the property of groups to which they belong. Insurance against loss, theft, or damage to such property occurring in the residence hall or elsewhere on campus must be arranged for by students or their parents through an insurance agent.

University Police makes available on its website a wide range of information about the university's security practices. View more information about the shuttle and escort service, community outreach, current investigations, crime prevention and safety education, and other programs and services by visiting www.cmu.edu/police (<https://www.cmu.edu/police/>).

Carnegie Mellon University publishes an annual campus security and fire safety report describing the university's security, alcohol and drug, sexual assault and fire safety policies, and containing statistics about the number and type of crimes committed on the campus, and the number and cause of fires in campus residence facilities during the preceding three years. You can obtain a copy by contacting the Carnegie Mellon Police Department at 412-268-2323. The annual security and fire safety report also is available online at www.cmu.edu/police/annualreports (<https://www.cmu.edu/police/annualreports/>).

Athletics and Physical Education

Josh Centor, Associate Vice President of Student Affairs and Director of Athletics, Physical Education & Recreation
 Location: Skibo Gymnasium, Tech and Frew Streets, Pittsburgh, PA, 15213
 Phone: 412-268-1236
 jcentor@andrew.cmu.edu
 www.cmu.edu/athletics (<http://www.cmu.edu/athletics/>)

Intercollegiate Athletics

Carnegie Mellon emphasizes excellence in its intercollegiate athletic programs, as well as in its classrooms. The university strongly believes that academic and athletic excellence can successfully coexist. Intercollegiate athletics are important in student life and make a positive impact on the educational experience. Experience as a student-athlete additionally provides benefits in professional and social endeavors following graduation.

Carnegie Mellon sports teams have competed intercollegiately since the early 1900s. In the past 16 years, the program has experienced extensive success. The Tartans have won 92 conference championships and competed in over 165 national championships since 1976. This success has been achieved while meeting all of the academic requirements of demanding programs and without athletic scholarships.

In 1986, Carnegie Mellon became a charter member of the University Athletic Association (UAA), an eight-team league of similar institutions with regard to academic and athletic programs. The UAA, a national association which geographically reaches as far north as Massachusetts, as far south as Atlanta and as far west as St. Louis and Chicago, sponsors intercollegiate competition in 23 sports including 10 for men and 10 for women. UAA members include Brandeis University, Case Western Reserve University, Carnegie Mellon University, Emory University, New York University, the University of Chicago, the University of Rochester and Washington University in St. Louis.

Carnegie Mellon, like the other seven UAA members, is a member of the National Collegiate Athletic Association (NCAA). Its intercollegiate teams compete on the Division III level, which prohibits athletic scholarships and operates under the true meaning of amateurism. Student-athletes who play at the varsity level are students first and athletes second. All students, both athletes and non-athletes, are treated equally with regard to admission and financial aid policies. Carnegie Mellon fully supports a policy of equity in resources and opportunities for women and men.

The university fields competitive teams in 19 sports. The Tartans compete in football, men's and women's golf, men's and women's soccer, men's and women's cross-country, men's and women's tennis, women's volleyball, men's and women's basketball, men's and women's swimming and diving, men's and women's indoor and outdoor track and field, and softball.

Carnegie Mellon's intercollegiate programs have consistently produced winners. The men's golf team won the university's first national championship in 2023 after placing sixth in 2022 and fourth in 2021. At the conclusion of the 2022 season, senior William Knauth was named the recipient of the Byron Nelson Award for his achievement in the classroom, on the course, and in the community, and a finalist for the Jack Nicklaus National Player of the Year Award.

The Tartans' football team has won 19 conference championships, the latest coming in 2022, had a string of 35 consecutive winning seasons from 1975-2009, and has appeared in the NCAA Division III Championship playoffs seven times. The Tartans have also played in seven ECAC Bowl games. In 1979, Carnegie Mellon was awarded the Lambert Trophy as the best small college team in the northeast. In 2019, senior defensive lineman Michael Lohmeier became the fifth Tartan named as a finalist for the William V. Campbell Trophy, an award that recognizes an individual as the absolute best scholar-athlete in the nation amongst all divisions.

The men's cross country team won its most recent conference championship in 2021 and has had a student-athlete or team compete at nationals for 21 straight seasons. In 2022, the women's cross country team made its fifth straight appearance and eighth overall at the national meet. The 1998 team placed fourth nationally, the highest in program history.

The volleyball team has made five trips to the NCAA Tournament in the past six seasons and reached their highest AVCA national ranking in program history when they held the sixth spot for two weeks during the 2017 season.

The women's soccer team has appeared in the NCAA tournament nine of the last 10 years. In 2019, the Tartans advanced to the NCAA Division III Women's Soccer Championship semifinals becoming the first women's team in Carnegie Mellon history to reach the semifinals of an NCAA tournament.

The men's soccer team has competed in postseason play 16 times since 2000, including 14 trips to the NCAA tournament. Jon Hall was named CoSIDA Men's Soccer Academic All-America of the Year in back-to-back years (2008 and 2009).

In 2015-16, the women's basketball team advanced to the Sweet 16 of the NCAA tournament for the first time in school history. The following season, 2016-17, senior Lisa Murphy was selected as the Jostens Trophy award winner. The award is a symbol of excellence for the Division III student-athlete; it is an honor given to the top women's basketball player for their excellence on the court, in the classroom and in the community. The 2021-22 team returned the program to postseason play and won the Eastern College Athletic Conference (ECAC) Championship for the second time in program history.

The men's basketball team had played in seven postseason tournaments since 2004-05 with the 2022-23 team playing in the ECAC Championship tournament after tying for fourth place in the UAA.

Kayvon Fatahalian, a freshman computer science major on the men's tennis team, won the NCAA National Singles Title in 2000 with a sophomore Abhishek Alla claiming the ITA National Small College Championship title in 2013. The women's tennis team also produced an ITA National Small College Champion when sophomore Amy Staloch won the singles title in 2006. The women's program has played in the NCAA Tournament in 16 of the last 17 years while the men's program has played in nine NCAA Tournaments, the latest in 2021.

Both men's and women's swimming and diving and track and field teams annually qualify a number of athletes for the national championships. Swimming has produced a combined nine national champions with the men's team finishing 11th in 2023 and the women 15th. The men's track and field team finished fourth at the 2022 NCAA Indoor Track and Field Championships with three athletes earning runner-up finishes in their respective events. In 2023, senior Liz Barre won the women's program's first indoor NCAA individual championship with a victory in the pentathlon while the men's program won the UAA Outdoor Championship for the fifth time.

In the spring of 2018, the women's golf team, competing in its fourth year of varsity competition, finished fifth at the NCAA Division III Championships. Then in 2020, the sixth year of the women's golf program, the Tartans landed at the top position in the final Division III national rankings by Golfstat. The number one ranking was the first for a women's team sport at Carnegie Mellon. The 2022 and 2023 team's placed fourth at the NCAA Championships.

The inaugural season of softball was in 2019. The team has produced four all-region honorees and set five team and four individual records in the 2023 season.

Carnegie Mellon has accumulated 192 Academic All-America honors given out by the College Sports Information Directors of America (CoSIDA) since 1973. There have been 147 that have earned the honor since the 2004-05 season. The Tartans have also produced 22 NCAA Postgraduate Scholars since 2007-08, which is a scholarship that is awarded to student-athletes who excel academically and athletically and who are in their final year of intercollegiate athletics competition.

In 2019, Carnegie Mellon Unveiled its Inaugural Athletics Hall of Fame. In October, 17 individuals and one historic team were inducted into the inaugural class.

To provide excellence throughout the athletic programs, the department employs full-time coaches in all varsity sports. Intercollegiate competition begins with the first football and soccer games in early September and ends with the NCAA track and field, golf, tennis and softball championships in late May. Students with athletic skills in any of the above mentioned sports are welcome to become members of the team. Participation is open to all students.

Recreation

In addition to providing for its more formal programs and teams, Carnegie Mellon's athletic facilities are available for use by individual students on an extensive seven-day per week schedule.

The Cohon University Center has facilities for swimming, basketball, volleyball, squash, and racquetball, as well as cardio and strength equipment. Gesling Stadium provides outdoor soccer, football and track facilities. Tennis courts, located between the University Center and Margaret

Morrison, are lighted for night play. Outside basketball courts are located near Donner Hall. During the school year, they are open for use by students, faculty and staff.

These facilities are available to students, faculty and staff who have a valid Carnegie Mellon ID card. For hours, contact the Athletic Office at 412-268-5635, or visit our website (<http://athletics.cmu.edu/landing/index/>).

Physical Education

The Department of Physical Education provides an elective program with an emphasis on personal fitness and lifetime recreation, thus preparing students for physical activity after the college years. Most classes are offered on a mini-course system with each class running seven weeks in length.

This program of more than 60 courses is designed for all students, from the beginner to those students who have already developed some skill. Courses include weight training, personal fitness, racquetball, tennis, golf, weight training, swimming, badminton, indoor cycling and yoga. The department offers a wide variety of diversity in our course offerings. Instruction is also provided in several team sports. Carnegie Mellon also provides courses for American Red Cross certification in the four levels of swimming and lifeguard training.

Intramural Sports

For those who seek another level of competition or just like to participate and have fun, the Intramural Program provides recreation and relaxation for all students, faculty and staff, regardless of the degree of their natural athletic skills. The university prides itself on an intramural program which annually has over 3,000 participants. Men and women, both graduate and undergraduate, compete in more than 20 different activities. Major sports include flag football, soccer, volleyball, floor hockey, basketball, and softball. A few of our popular tournaments are ultimate frisbee, dodgeball, tennis, and badminton.

Through participation in this program, students are able to keep physically fit, put to good use various learned skills, and develop leadership, team play and sportsmanship. Intramural activities, like all sports endeavors, contribute to physical development, good health, and a sound state of mind, while providing keen competition and team spirit. In addition, intramural sports possess an inherent flexibility that allows for a limited commitment of time in light of academic priorities. The intramural program permits students from all departments to meet and socialize on an informal basis.

Fitness and Wellness

The university is well aware that fitness is a vital contributor to an individual's well-being and productivity. For this reason the department is committed to providing the entire campus community with the opportunity and resources to keep fit for the new century.

The Fitness and Wellness program provides educational services, programs, workshops and seminars. The Group X program provides over 70 exercise classes per week ranging from yoga and pilates to zumba and indoor cycling. These classes are free for all full time CMU students, faculty and staff. Personal training sessions are available for cost and provide an opportunity to work one on one with a certified strength coach in our athletic facilities.

Faculty

GARY ALDRICH, Associate Head Track & Field Coach/Instructor - M.S., Slippery Rock University, Carnegie Mellon, 2006-

MICHAEL BELMONTE, Assistant Men/Women Tennis - History, Duquesne; Carnegie Mellon, 2010-

BRANDON BOWMAN, Head Men's Soccer Coach - B.S., Centre College; Carnegie Mellon, 2017-

JOSH CENTOR, Assistant Director of Athletics - B.A., Brandeis University, Carnegie Mellon, 2008-

ALAN DEGENNARO, Strength and Conditioning Coach, Carnegie Mellon, 2011-

SARA GAUNTNER, Assistant Director of Athletics for Instructional Programs & Recreation & Aquatics Director/Instructor - M.S., Duquesne University, Carnegie Mellon, 2005-

ANDREW GIRARD, Head Men's and Women's Tennis Coach/Instructor - B.S., Michigan Tech University, Carnegie Mellon, 2003-

ALICIA GORMAN, Diving Coach, Director of Aquatics - B.S., University of Tennessee; Carnegie Mellon, 2017-

ANDREW HELMS, Assistant Football Coach - B.S., Carnegie Mellon University; Carnegie Mellon, 2017-

JACQUIE HULLAH, Head Women's Basketball Coach, Carnegie Mellon, 2011-

KIM KELLY, Head Women's Volleyball Coach/Instructor - MBA, Mt. St. Mary's University, Carnegie Mellon, 2005-

MATTHEW KINNEY, Head Swimming and Diving Coach/Instructor - M.S., Western Illinois, Carnegie Mellon, 2007-

RICHARD LACKNER, Head Football Coach/Instructor - B.A., Carnegie Mellon, Carnegie Mellon, 1979-

JEFF SIMMONS, Assistant Football Coach/Instructor - B.A., Geneva College; Carnegie Mellon, 2010-

PATTY STRAGAR, Operations Manager for Fitness and Aquatics/Instructor - B.S., Northwestern University; Carnegie Mellon, 2003-

YON STRUBLE, Head Men's Soccer Coach/Instructor - M.S., Georgia State; Carnegie Mellon, 2010-

TONY WINGEN, Head Men's Basketball Coach/Associate Athletic Director/Instructor - M.Ed., Springfield College; Carnegie Mellon, 1990-

Department of Athletics and Physical Education Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

69-005 Intro to Fly Fishing

Fall and Spring: 3 units

This introductory class explores the fundamentals of fly fishing. Aimed at the novice fly angler, topics include equipment selection, knot tying, basic entomology and fly selection, reading the water, and where to fly fish in Western Pennsylvania. Fly casting, the most important aspect of fly fishing, is taught.

69-101 Racquetball

Fall and Spring: 3 units

This course is designed to aid in developing the fundamental skills involved in racquetball. Techniques, rules and strategy are stressed. It is hoped that the student will develop a reasonable level of proficiency to enable participation on a leisure-time basis.

Course Website: <http://www.cmu.edu/athletic/>

69-102 Weight Training

Fall and Spring: 3 units

This course is designed to provide the opportunity for the inexperienced student to learn the effectiveness of a carefully planned weight-training program as a method of body development and the contributing benefit to performance in many sports.

69-103 Advanced Recovery & Restoration

Spring: 3 units

This course is designed to provide the opportunity for the physically active student to learn the effectiveness of a carefully planned recovery and restoration techniques as a method of body development and the contributing benefit to performance in many sports.

69-104 Practical Application of Sports Nutrition for Competitive Athletes

Spring: 3 units

This course will cover the following topics: macronutrient overview, specific overview of fats, carbohydrates, and protein, vitamin and minerals, nutritional needs for strength/power and endurance athletes, pre/during/post training nutritional needs for strength/power and endurance athletes, and other topics. FOR UNDERGRAD STUDENTS ONLY.

69-105 Agility & Circuit Training

Spring: 3 units

This course is designed to train the entire body combining fitness and core body work. We will do jumping and agility exercises to increase explosiveness and foot speed. Circuit training will be used to strengthen your core, arm, and leg muscles and will provide a cardiovascular workout.

69-106 Intro to Recreation

Fall: 3 units

This is a basic level class for first-year students only. This class is designed to teach students various fitness and recreational activities available to them on campus.

69-107 Walking for Fitness

Fall: 3 units

THIS COURSE IS IN PERSON ONLY FALL 2021. This course is an aerobic conditioning activity. A fast paced walk that is less wear and tear on your joints than what a running program will do.

69-110 Personal Fitness

Fall and Spring: 3 units

THIS COURSE IS IN PERSON ONLY FALL 2021. This course will be a conditioning course prescribed partially by the individual with assistance from the instructor to insure that the desired results will be achieved or at least pursued correctly. Individual goals will be the main concern. Stretching, aerobics, weight training and nutrition will be discussed.

69-112 Fitness Fusion

Fall and Spring: 3 units

A fun power-packed workout designed to introduce all aspects of fitness. This class combines simple exercises including cardio endurance with dynamic balance and stabilization. The class will fuse fitness while maximizing the benefits offered by training with concise, innovative, and effective exercises for the whole body. Every few weeks another aerobic activity will be added. We will start slowly so you can experience progressions and advance your training. During the fusion of strength, core, and flexibility, we will use a variety of "toys" to enhance your fun and fitness while fusing the total package of mind, body, and spirit.

69-113 Beginning Karate

Fall and Spring: 3 units

Beginning Karate teaches traditional Tang Soo Do (Korean Karate) by Master C. S. Kim and assistant instructors with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Students will learn stretching and basic stances as well as blocking, punching, kicking, knee and elbow strikes, and open-handed techniques such as knife-hands. Proper etiquette will also be taught.

69-114 Intermediate Karate

Fall and Spring: 3 units

Intermediate Karate teaches a higher level of the traditional martial arts with specific standards and goals designed to help each student maximize potential as an individual, as well as a martial artist. Through traditional Tang Soo Do (Korean Karate) taught by Master C. S. Kim and assistant instructors, you will find many opportunities to gain specific knowledge which will apply not only in your martial arts training, but also in the improvement of your daily quality of life.

69-120 Topics in Health and Physical Activity

Fall and Spring: 3 units

This course is a weekend seminar covering a variety of topics. Dates of the course are: Friday, March 17th - 4:00-7:00, Saturday, March 18th - 9:00 - 2:00 and Sunday, March 19th - 9:00 - 2:00 . This course is designed to expose students to a comprehensive overview of what it means to be healthy, including: stress management strategies, healthy eating habits, importance of sleep, and the benefits of various exercise methods. The course will be presented using both a traditional lecture style, and hands-on practice. A few outside speakers will be brought in to speak in their area of expertise. Students should come prepared to exercise.

69-129 Rape Agression Defense Systems (RAD)

Fall and Spring: 3 units

Self Defense for Women - is a course specifically designed to increase women's awareness of potential sexual assault and to provide physical techniques to respond to such an act. It is intended for women only because it is believed that the presence of males in class (other than instructors or other authorized persons) can alter the emotional and physical responses of women to class material and thereby hinder their ability to reach course objectives. It is of the utmost importance that women be able to maximize their opportunity to learn in the company of like-minded students. The core of the course is based upon the principles of the Rape Aggression Defense System (R.A.D.) which was conceived and developed by Larry N. Nadeau. His goal in developing R.A.D. is also its motto: "To develop and enhance the options of self-defense, so they may become viable considerations to the woman who is attacked." This course is composed of three sections: risk reduction principles, physical defense techniques, and simulation. Risk reduction principles include a thorough review of personal self-awareness and the environment, whether in the home, neighborhood, or unfamiliar community. Physical defense techniques include the introduction to bodily strikes with hands, kicks with the feet, and defenses against grabs and holds. Simulation is the activity that attempts to incorporate, via physical demonstration, all emotional and physical techniques that have been taught through the acting out of scenarios involving instructors (padded/protected) as attackers, and students (padded/protected) responding to the assault.

69-130 Beginning Tennis

Fall and Spring: 3 units

This course is designed to familiarize the student with the rules of tennis and to develop the skills needed to become proficient for recreational play. During the first half of the course, all tennis strokes will be covered and reviewed in detail. The second half of the course will focus mostly on competitive games and match-play.

69-131 Volleyball

Spring: 3 units

This course is designed to familiarize the student with the rules of volleyball and to develop the skills needed to become proficient for recreational play.

69-132 Advanced Tennis

Fall: 3 units

This course will consist mainly of tennis drills and discussions related to singles, doubles, and match strategy. In addition to being able to successfully execute all tennis strokes, students should also already have significant tennis match experience.

69-134 Beginning Golf

Fall and Spring: 3 units

This course is designed to give the student all the skills necessary to play a satisfactory game of golf. The long game, the short game and putting are covered. It is a leisure time sport that is challenging and can be used by the student for the rest of his/her life.

69-135 Soccer Skills

Spring: 3 units

This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-136 Basketball Skills

Fall and Spring: 3 units

This course is designed to familiarize the student with the rules of basketball and to develop the skills needed to become proficient for recreational play.

69-137 Ultimate Frisbee

Fall: 3 units

This class is designed to teach basic Frisbee skills. This class is a great conditioning/cardio class with high energy. It is a fun team game to play.

69-139 Indoor Soccer Skills

Spring: 3 units

This course is designed to familiarize the student with the rules of soccer and to develop the skills needed to become proficient for recreational play.

69-140 Squash

Fall and Spring: 3 units

This course is designed to aid in developing the fundamental skills involved in squash. Techniques, rules and strategy are stressed.

69-141 Beginning Soccer

Spring: 3 units

This class is designed for beginner soccer players. This class will teach you soccer skills and techniques to become a better player.

69-142 Beginning Fencing

Spring: 6 units

This course will cover the basic skills needed for fencing with the foil. Footwork, attacks, and defenses will be practiced. Competition rules and strategies will be discussed. Students will fence each other and the instructor in almost every class.

69-143 Dodgeball

Spring: 3 units

This class is designed to teach the rules of dodgeball. The students will learn the national rules and play against classmates.

69-144 Diamond Sports

Spring: 3 units

This course is designed to familiarize the student with the rules of softball and wiffleball and to develop the skills needed to become proficient for recreational play. Students will play each other or the instructor in almost every class.

69-145 Beginning Softball

Fall and Spring: 3 units

Students will learn beginning softball skills-throwing, hitting, running

69-146 Team Handball

Fall: 3 units

Team Handball or European Handball - This is an introductory level class that will cover the basics of the sport including the rules, organization, and basic game play. Students will be expected to learn the rules and participate in play on a daily basis.

69-150 Beginning Swimming

Fall: 3 units

This basic course is designed to equip the non-swimmer with fundamental skills and knowledge to assure reasonable safety in, on or about the water. Areas covered include the basic swimming strokes, basic diving, safe and efficient entry into the water, and some elementary forms of rescue.

69-151 Introduction to Yoga

Fall and Spring: 3 units

THIS COURSE IS IN PERSON ONLY FALL 2021. This course is designed for the beginning yoga student who wants to gain a solid foundation of yoga poses and the benefits a yoga practice has to offer. The course is also for those who have experience in Yoga and want to practice and improve their basic skills.

69-153 Lifeguard Training

Spring: 3 units

This class is the American Red Cross Lifeguard Training course. Students who complete certification will be eligible to be employed as lifeguards. Attendance is required. There will be a \$90.00 fee for this class from the American Red Cross. This fee will be deducted from the student's account once the status of the student is "enrolled and attending this class." A minimum of six students registered is needed to successfully run this course.

69-155 Cardio Fitness/Sculpt

Fall and Spring: 3 units

A total body fitness class for men and women that incorporates stretching for flexibility, exercises for strength and movement to increase cardiovascular improvement.

69-156 First Aid/CPR

Spring: 3 units

A basic course in treatment and care of injuries in emergency situations. Topics will include legal liability, prevention of injuries, nutrition and cardiovascular conditioning. The course will conclude with theoretical and practical application of cardiopulmonary resuscitation. Upon completion of the course students will receive Red Cross Certification. There will be a fee for this class of \$15.00. This fee will be deducted from the student's account.

69-157 Swimming Stroke Improvement

Fall: 3 units

This course is designed to provide the student with the opportunity to learn the elements of good swimming. A wide range of strokes, basic diving, safety, endurance, and versatility in the water will be covered for all students. Experienced swimmers will have the opportunity to perfect their strokes.

69-160 Swim-Fit

Fall and Spring: 3 units

Must be able to complete a 1000 yard swim (40 laps) prior to entering the class ; this is not a learn-to-swim class. Pre and post timed swims, deep water treading, lap swimming interval training. Average workout is around 2000 yards.

69-165 Cycling Core

Fall and Spring: 3 units

Indoor cycling classes are riding on a stationary bike while getting a great workout, experiencing several styles of training, and listening to music. All are welcome and #8212;beginner to advanced and #8212;you set the workout pace to various intensities. This course is for those participants who want to gain knowledge and experience of riding for endurance, speed work, race training, strength training, and/or visionary riding. Each class will be formatted to take the rider to their levels of advancement and #8212;beginner to advanced and #8212;all doing the same workout. Bikes are provided. No prior bike experience is necessary. No special footwear required and #8212;bike shoes are welcome and #8212;and tennis shoes at least are a must. Come along for the ride of a lifetime while having fun and getting into shape.

69-167 Beginning Ballroom Dance

Spring: 2 units

This class provides an overview of six American Style Ballroom Dances: Foxtrot, Waltz, Tango, Cha Cha, Rumba, Swing. Participants will learn three or four basic step patterns in each dance, the timing of each pattern, leading and following principles and the unique characteristics of each dance. At the end of this course, participants will be able to dance comfortably at a social dance. It is recommended that suede bottomed dance shoes be worn, but not required.

69-175 African-Brazil Dance

Fall: 2 units

This class incorporates African-Modern dance technique (specifically elements of Dunham and Horton technique) and applies it to dance movements from West Africa, Haiti, and /or Brazil. Students will build strength, alignment, and stamina while experiencing the joy of dancing to the exciting and mesmerizing music of these regions. Open to non-drama and drama majors.

69-176 Non-Majors Jazz

Spring: 3 units

This class is designed for those students who would like to continue their study in jazz but are not enrolled in the CFA department. They will learn the basics and progression movements in the area of jazz dancing. This is for all levels of participants.

69-195 Emergency Medical Technician 1

Fall and Spring: 12 units

The Emergency Medical Technician provides students with a basic knowledge of Emergency Medicine, and enables students to take the National Registry EMT Certification exam and become certified at the state and national level. This course is cross-enrolled through the Community College of Allegheny County (CCAC) and will require registration with CCAC on the first day of class. This will require a fee, which has yet to be determined. Due to state laws and classroom hours requirements, all lectures are mandatory with very few exceptions. This class will meet on around 2 Saturdays, which will be announced on the first day of class. This class is also offered in two parts. The first part (69-195) is offered during mini-2 and the second part (69-195) is offered during the full spring semester. You must attend both parts in order to be eligible to take the National Registry EMT Certification exam. Please email info@cmuems.org with any questions you might have.

Reserve Officers' Training Corps (ROTC)

Department of Aerospace Studies (Air Force ROTC)

Lt Col James Straub, *Detachment 730 Commander*

Location: University of Pittsburgh, 4200 Fifth Avenue, 2917 Cathedral of Learning

Phone: 412-624-6031

afdet730@pitt.edu

www.afrotc.pitt.edu (<http://www.afrotc.pitt.edu>)

The local AFROTC program is administered by the Department of Aerospace Science at the University of Pittsburgh. This program is available to undergraduate students at fourteen "cross-town" universities via enrollment through agreement with the University of Pittsburgh. Students must have at least six semesters (three full academic years) of school remaining to successfully complete AFROTC graduation requirements. Upon successful completion of university academic and ROTC requirements, students will earn a commission as a Second Lieutenant in the US Air Force.

Students will complete one or two years in the General Military Course (GMC) before competing for an enrollment allocation into a four-week summer leadership training program. After completion of the summer training program, students are enlisted into the Professional Officer Course (POC), where they will take on role leading anywhere from 10-50 of their fellow cadets in weekly activities. *Students are under NO contractual obligation to the Air Force until entering the POC or accepting an Air Force scholarship.* In addition to the academic portion of the curriculum, each student attends a weekly two-hour, hands-on "laboratory" that tests both their followership and leadership abilities amongst their peers. This lab is used to practice various leadership and management techniques and groom students into future military leaders. Three and three-and-a-half year scholarships are available to qualified students in certain areas of study. Most AFROTC scholarships cover tuition plus lab fees, books, plus each scholarship awardee receives a tax free monthly stipend that ranges between \$300-500 per month.

Department of Military Science (Army ROTC)

William Perez, *Army ROTC, Three Rivers Battalion Scholarship and Enrollment Officer*

Location: University of Pittsburgh, 315 South Bellefield Avenue, Room 306

Phone: 412-624-6254

Fax: 412-624-7793

WRP14@pitt.edu

The Army Reserve Officers' Training Corps (ROTC) program supporting Carnegie Mellon University is located at the University of Pittsburgh. It exists to train the future officer leadership of the United States Army and offers opportunities and challenges that can put college students on the fast track to success in life. ROTC provides a combination of academics and important hands-on training, in addition to physical and mental challenges that will help students succeed in college and beyond. Through the training in ROTC, students will develop the confidence, self-esteem, motivation and leadership skills they will need regardless of their career plans.

The Four-Year Program

The traditional Four-Year program is divided into two parts. The Basic Course is taken in the freshman and sophomore years. There is no commitment for non-scholarship students at this level. Upon successful completion of the Basic Course, students are eligible for the Advanced Course, taken in the junior and senior years. At the beginning of the Advanced Course, students will decide whether or not they wish to become officers in the Army and enter into a formal contract. During the summer between the junior and senior years, students are required to attend the Leader Development and Assessment Course (LDAC). Upon successful completion of a University degree and the Army ROTC program, students are commissioned into the United States Army as a Second Lieutenant.

The Two-Year Program

If the first two years of ROTC are not taken, students can attend the Leader's Training Course (LTC) during the summer between the sophomore

and junior year. This camp will qualify students to begin the Advanced Course in their junior year or in the first year of a two-year graduate program. Or, if students have served in the active duty military, attended a military academy for one year, participated in JROTC for three years or belong to a Army National Guard or Army Reserve unit, they already qualify for entrance into the Advanced Course.

The Alternative Entry Program

The Alternative Entry Program is designed for academic junior students with no prior qualifying military training but are otherwise qualified. This option allows students to contract into the Advanced Course without receiving placement credit for the basic course. Students accepted into this program must complete the Leader's Training Course and the Leader Development and Assessment Course during the summer months.

Curriculum

| Freshman Year | | Units |
|--|--|-------|
| 30-101 | Introduction to Military Leadership - Fall | 5 |
| 30-102 | Foundations of Leadership- Spring | 5 |
| Sophomore Year | | Units |
| 30-201 | Leadership Dynamics and Application- Fall | 5 |
| 30-202 | Applications in Leadership and Combat Power- Spring | 5 |
| Junior Year | | Units |
| 30-301 | Basic Leader Planning and Combat Operations- Fall | 5 |
| 30-302 | Advanced Leader Planning and Combat Operations- Spring | 5 |
| Leadership Development & Assessment Course (six-week required summer camp) | | |
| Senior Year | | Units |
| 30-401 | Progressive Leadership Theory and Applications- Fall | 5 |
| 30-402 | Transition to the Profession of Arms- Spring | 5 |

Army ROTC Scholarships

Army ROTC offers four, three and two year full scholarships with additional annual allowances of \$900 for books and a monthly stipend. High school, undergraduate and incoming two-year graduate students are eligible to apply. For application and information call ROTC at the University of Pittsburgh at (412) 624-6254/6197.

The Simultaneous Membership Program (SMP)

This program allows students to become members of the Army National Guard or the Army Reserves while enrolled in Army ROTC. Students in the Advanced Course who are SMP are paid for their Guard/Reserve training. The benefit of this program is that students in the Advanced Course are able to act as Army officers in their National Guard or Reserve unit, receiving valuable leadership experience.

Summer Programs

Leadership Development & Assessment Course

This 35-day camp is a requirement for all contracted students. Students attend the summer between their junior and senior year. Students are placed in various leadership positions throughout Camp and their skills and abilities will be tested and evaluated in preparation of a commission in the United States Army. All expenses are paid by the Army. Students are paid while attending.

Leader's Training Course

This 35-day camp is taken as a prerequisite for entry into the Advanced Course if the Basic Course cannot be fulfilled. It is taken the summer before the junior year. All expenses are paid by the Army. Students are paid while attending.

Army Adventure Training

ROTC students may participate in Airborne School, Air Assault School, Northern Warfare School and Mountain Warfare School the summer before

the sophomore and junior year. These courses range from two to four weeks and students must arrive in top physical condition. All expenses are paid by the Army.

Extracurricular Activities

Rangers: Army ROTC students are eligible to participate in the Cadet Ranger Club. The Club conducts physically and mentally challenging extracurricular training to promote fitness, teamwork, self-confidence and fellowship. Training includes physical fitness, rappelling, rope bridging, tactics, hiking, climbing, weapons training and orienteering.

Scabbard & Blade: National Honor Society consisting of cadets/midshipmen from Army, Air Force and Naval ROTC.

Rho Tau Chi: Military fraternity established for the members of the various branches of ROTC. Purpose is to draw together cadets to increase communication and feelings of goodwill between the Cadet Corps and the community. Cadets participate in a variety of community service projects.

Color Guard: Dedicated group of Army ROTC cadets who train and perform to present the American flag and Army colors at football and basketball games and various community events.

Department of Naval Science (Naval ROTC)

Mike Danko, ROTC and Veterans Affairs Coordinator
Captain Michael Tomon, U.S.N., Commanding Officer

Location: 4615 Forbes Avenue

Phone: 412-268-5109

Fax: 412-268-6381

www.cmu.edu/nrotc (<https://www.cmu.edu/nrotc/>)

The Department of Naval Science was established 16 December 1987. Its mission is to prepare young men and women mentally, morally, and physically, and to instill in them the highest qualities of duty, honor, and loyalty, in preparation for leadership positions in the naval service.

Carnegie Mellon's Naval Reserve Officers Training Corps (NROTC) is designed for young men and women who are seeking a challenging academic experience and who desire to serve their country as officers in the Navy or Marine Corps after graduation.

NROTC midshipmen lead the same campus life as other Carnegie Mellon students. They make their own arrangements for room and board, choose a preferred area of study and participate in extracurricular activities. Midshipmen wear civilian clothes to classes but wear uniforms one day of the week. NROTC students are active in all facets of university life; many are in positions of leadership in student government, on varsity and intramural sports teams, in campus clubs, and other student organizations. The NROTC program seeks students who are bright, ambitious, enthusiastic leaders whose lives are enriched by their education at Carnegie Mellon and by their involvement in NROTC.

Four-Year Scholarship Program

The four-year scholarship program provides full tuition and university fees, \$750 for textbooks per year, uniforms, and a \$250 per month tax-free subsistence allowance to students during their freshman year. This stipend then increases to \$300 during their sophomore year, \$350 for their junior year and \$400 for their senior year. Midshipmen must complete the university-approved curriculum of their choice, including courses in calculus and calculus-based physics (Navy Option Only), and specified courses in naval science subjects. Paid summer training periods are also provided. Scholarships are awarded on the basis of a nationwide competition before the start of the freshman year. Midshipmen commissioned through the scholarship programs become officers in the Navy or Marine Corps and incur a four-year active duty obligation in a selected area of the naval service.

College (Non-Scholarship) Programs in NROTC

Qualified students may participate in NROTC as college program (non-scholarship) midshipmen and earn commissions in the Navy or Marine Corps Reserve upon graduation. The active duty obligation for this program is three years. Students receive all naval science textbooks and uniforms. Additionally, if awarded advanced standing during their junior and senior years, they receive a tax-free subsistence monthly allowance of \$350 and \$400 respectively. A paid summer training period is provided between the junior and senior year. College program students may compete for three- and two-year scholarships described in the following paragraph.

College Program Three- and Two-Year Scholarships

Three-year scholarships are available on a competitive basis to those qualifying college program (non-scholarship) NROTC students who have demonstrated leadership and academic excellence during their freshman or sophomore year and are nominated for the scholarship by the Professor

of Naval Science. Scholarship benefits are identical to those provided by the four-year scholarship program. Active duty obligation is four years upon commissioning in a selected area of the naval service.

Two-Year National Scholarship Program

Sophomores who have not participated in the NROTC program may apply for a nationally competitive two-year NROTC scholarship. The two-year scholarship program provides the same benefits as the four-year program for a period of 20 months. Students must apply for this program no later than February of their sophomore year. Students selected for this program attend the Naval Science Institute during the summer before their junior year to complete required naval science course material. A paid summer training period is provided between the junior and senior years. Commissionees incur a four-year active duty obligation upon graduation in a selected area of the naval service.

Curriculum

The sequence of naval science courses is the same for all officer candidates for the first three semesters. Midshipmen accepted into the Marine Corps option program will have curriculum variations starting with their third year. Additionally, some candidates may be required to complete courses in American military affairs, national security policy, English, mathematics, and/or the physical sciences. Descriptions of the course requirements for each candidate classification (scholarship/college program) may be obtained from the Department of Naval Science office.

All scholarship and college program students are required to attend a weekly 1.5 hour Naval Laboratory (32-100) where professional orientation, military drill, physical fitness, and leadership are emphasized. Guest speakers from the Fleet are frequent participants in these laboratories. Naval Science courses are open to all students. Since these are required courses for NROTC students, they will be given priority in enrollment. Remaining spaces will be filled through the normal university registration process.

Naval Professional Academic Courses

| Freshman Year | | Units |
|----------------|--|-------|
| 32-100 | Naval Laboratory | 3 |
| 32-101 | Introduction to Naval Science | 6 |
| 32-102 | Seapower and Maritime Affairs | 6 |
| Sophomore Year | | Units |
| 32-200 | Naval Laboratory | 3 |
| 32-201 | Leadership & Management | 9 |
| 32-212 | Navigation * | 9 |
| Junior Year | | Units |
| 32-300 | Naval Laboratory | 3 |
| 32-310 | Evolution Of Warfare ** | 9 |
| 32-311 | Naval Ship Systems I-Engineering * | 9 |
| 32-312 | Naval Ship Systems II-Weapons * | 9 |
| Senior Year | | Units |
| 32-400 | Naval Laboratory | 3 |
| 32-402 | Leadership and Ethics | 9 |
| 32-410 | Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare | 9 |
| 32-411 | Naval Operations and Seamanship * | 9 |

Footnotes:

* Required of students in the Navy Option

** Required of students in the Marine Option

All other courses are required of all students in the program.

Naval ROTC Faculty

JEFF CORAN, Captain, USN - M.S., Rensselaer Polytechnic Institute; Carnegie Mellon, 2014-

ROTC Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

Aerospace Studies-ROTC Courses

31-101 Foundations of the United States Air Force

Fall: 3 units

AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-102 Foundations of the United States Air Force

Spring: 3 units

AS100 is a survey course designed to introduce cadets to the United States Air Force and Air Force Reserve Officer Training Corps. Featured topics include: mission and organization of the Air Force, officership and professionalism, military customs and courtesies, Air Force officer opportunities, and an introduction to communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-105 Air Force Leadership Laboratory

All Semesters

The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-106 Air Force Leadership Laboratory

All Semesters

The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-107 Air Force Leadership Laboratory

All Semesters

The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-108 Air Force Leadership Laboratory

All Semesters

The AS100 and AS200 Leadership Laboratory courses (LLABs) include a study of Air Force customs and courtesies, drill and ceremonies, and military commands. The LLAB also includes studying the environment of an Air Force officer and learning about areas of opportunity available to commissioned officers. The AS300 and AS400 LLABs consist of activities classified as leadership and management experiences. They involve the planning and controlling of military activities of the cadet corps, and the preparation and presentation of briefings and other oral and written communications. LLABs also include interviews, guidance, and information, which will increase the understanding, motivation, and performance of other cadets.

31-201 The Evolution of Air and Space Power

Fall: 3 units

The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-202 The Evolution of Air and Space Power

Spring: 3 units

The AS200 course designed to examine general aspects of air and space power through a historical perspective. Utilizing this perspective, the course covers a time period from the first balloons and dirigibles to the space-age global positioning systems of the Persian Gulf War. Historical examples are provided to extrapolate the development of Air Force capabilities (competencies), and missions (functions) to demonstrate the evolution of what has become today's USAF air and space power. Furthermore, the course examines several fundamental truths associated with war in the third dimension: e.g. Principles of War and Tenets of Air and Space Power. As a whole, this course provides the cadets with a knowledge level understanding for the general element and employment of air and space power, from an institutional doctrinal and historical perspective. In addition, the students will continue to discuss the importance of the Air Force Core Values with the use of operational examples and historical Air Force leaders and will continue to develop their communication skills. Leadership Laboratory is mandatory for AFROTC cadets and complements this course by providing cadets with followership experiences.

31-301 Air Force Leadership Studies

Fall: 9 units

AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-302 Air Force Leadership Studies

Spring: 9 units

AS300 is a study of leadership, management fundamentals, professional knowledge, Air Force personnel and evaluation systems, leadership ethics, and the communication skills required of an Air Force junior officer. Case studies are used to examine Air Force leadership and management situations as a means of demonstrating and exercising practical application of the concepts being studied. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences in officer-type activities, giving students the opportunity to apply the leadership and management principles of this course.

31-401 National Security Affairs and Preparation for Active Duty

Fall: 9 units

AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

31-402 National Security Affairs and Preparation for Active Duty

Spring: 9 units

AS400 examines the national security process, regional studies, advanced leadership ethics, and Air Force doctrine. Special topics of interest focus on the military as a profession, officership, military justice, civilian control of the military, preparation for active duty, and current issues affecting military professionalism. Within this structure, continued emphasis is given to refining communication skills. A mandatory Leadership Laboratory complements this course by providing advanced leadership experiences, giving students the opportunity to apply the leadership and management principles of this course.

Military Science-ROTC Courses

30-101 Introduction to Military Leadership

Fall: 5 units

In this course, students will be introduced to the fundamentals of Army leadership, management and basic military skills. The course emphasizes the Army's "Principles of Leadership" and familiarizes the student with rifle marksmanship, orienteering and map reading, rappelling, basic lifesaving skills and the wear of the Army uniform. In addition, students will enhance their time management, decision-making and physical fitness abilities. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-102 Foundations of Leadership

Spring: 5 units

This course is a continuation of the subjects and skills taught in 30101. In addition to extending the student's abilities in the areas of leadership, orienteering and map reading, lifesaving and other basic military concepts, the course also introduces the student to the employment of military units. Individual topics covered include the Army's emerging technological enhancements, the Army organization and structure and the wartime policies and principles. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-201 Leadership Dynamics and Application

Fall: 5 units

In this course, students will delve more deeply into the Army's leadership and management techniques, including the application of those techniques in faculty-supervised practical exercises. The course also seeks to enhance the student's abilities in orienteering and map reading, terrain analysis, advanced lifesaving techniques and physical fitness. Students are introduced to the values that define the United States Army as an American institution, and each student continues to enhance his or her physical development under the supervision of the faculty. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-202 Applications in Leadership and Combat Power

Spring: 5 units

This course continues the study of the topics covered in 30201 and focuses upon practical application of the leadership and management techniques learned in the fall semester. The student develops and applies advanced map reading, terrain analysis, problem-solving and decision-making skills in practical exercises. Additionally, the student is introduced to the Army's formal orders process, used to maneuver and sustain Army forces on the modern battlefield. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided.

30-301 Basic Leader Planning and Combat Operations

Fall: 5 units

This course offers an in-depth analysis and focused practical application of leadership and management techniques. The emphasis in the course is on leader development and the goal is to enhance the student's ability to perform effectively in a stressful decision-making environment. As such, time management, decision-making, advanced military skills, troop-leading procedures and advanced physical training are emphasized. The course requires participation in a demanding physical training program to prepare contracted students for the Army's R.O.T.C. Leader Development and Assessment Course (LDAC). Each student must participate in field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-302 Advanced Leader Planning and Combat Operations

Spring: 5 units

This course builds upon the foundation laid in the fall semester with the objective of fully preparing contracted students for participation in the Army's challenging R.O.T.C. Leader Development and Assessment Course (LDAC). The course extends and enhances the student's leadership, management, communication, fitness and basic military skills in preparing the student for commissioning as an officer in the United States Army. Practical exercises are used to reinforce all of the skills that the student has developed over the course of the military science instruction. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students. Veterans with two or more years of service may enroll with approval.

30-401 Progressive Leadership Theory and Applications

Fall: 5 units

This course is the first of two semester courses that serve as a capstone designed to transition the student from cadet to U.S. Army officer. Students are assigned to command and staff positions within the cadet battalion, corresponding to those found in United States Army units. Students perform the duties of the staff or command as assigned and interact with the other cadets as part of a functioning command organization. In addition to studying the operations and organizations of the U.S. Army, students are required to plan and execute the required training and activities in leading the underclass cadets. A variety of topics of current interest are covered. Guest speakers are commonly invited to discuss their military experiences or their perspectives on military-related topics. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

30-402 Transition to the Profession of Arms

Spring: 5 units

This capstone course completes the transition from cadet to Army officer and concludes with the student's commissioning into the United States Army. During the semester, students continue to act in accordance with their assigned staff and command responsibilities and they prepare for their duties as a Lieutenant in the Army. This course covers personal and performance counseling, evaluation of subordinate leaders and team-building skills as well as military justice and discipline. Students bring to bear all of the skills and knowledge that they have accrued over the prior semesters in the Department of Military Science. Each student must participate in physical training, field training exercises and is expected to wear the Army uniform, which will be provided. Prerequisites: Class is open only to contracted students.

Naval Science - ROTC Courses

32-100 Naval Laboratory

Fall and Spring: 3 units

Military drill, physical fitness, and leadership seminars.

32-101 Introduction to Naval Science

Fall: 6 units

A general introduction to the naval profession and to concepts of Seapower. Instruction emphasizes the mission, organization, and warfare components of the Navy and Marine Corps. Included is an overview of officer and enlisted ranks and rates, training and education, and career patterns. The course also covers naval courtesy and customs, military justice, leadership, and nomenclature. This course exposes the student to the professional competencies required to become a naval officer.

32-102 Seapower and Maritime Affairs

Spring: 6 units

This course surveys US naval history from its European origins to the present with emphasis on major developments and the geopolitical forces shaping these developments. Also included is discussion of the theories and writings of naval historian and strategist Alfred Thayer Mahan. The course will finish by covering present day concerns in seapower and maritime affairs including the economic and political issues of merchant marine commerce, the law of the sea, the navy and merchant marine of the former Soviet Union (FSU), and a comparison of US and FSU maritime strategies to include the rise and decline of the Soviet Navy.

32-200 Naval Laboratory

Fall and Spring: 3 units

Military drill, physical fitness, and leadership seminars.

32-201 Leadership & Management

Fall: 9 units

This course is a comprehensive advanced-level study of organizational behavior and management. Topics include a survey of the management functions of planning, organizing, and controlling; an introduction to individual and group behavior in organizations; an extensive study of motivation and leadership. Major behavioral theories are explored in detail. Practical applications are explored by the use of experiential exercises, case studies, and laboratory discussions. Other topics developed include decision-making, communication, responsibility, authority and accountability.

32-212 Navigation

Spring: 9 units

An in-depth study of piloting and an introduction to celestial navigation theory. Students learn piloting skills including the use of charts, visual and electronic aids, and the theory and operation of magnetic and gyro compasses. Students develop practical skills in both piloting and celestial navigation. Other topics include tides, currents effects of wind and weather, plotting, use of navigation instruments, types and characteristics of electronic navigation systems, and the typical day's work in navigation. Also included is a study of the international and inland rules of the nautical road, relative motion, vector analysis theory, and relative motion problems.

32-300 Naval Laboratory

Fall and Spring: 3 units

Military drill, physical fitness, and leadership seminars.

32-310 Evolution Of Warfare

Spring: 9 units

This course is to provide the student with a very basic understanding of the art and concepts of warfare from the beginning of recorded history to the present day. The intent of the curriculum is to familiarize the student with an understanding of the threads of continuity and the interrelations of political, strategic, operational, tactical, and technical levels of war from the past, while bringing into focus the application of these same principles and concepts to the battlefields of today and the future.

32-311 Naval Ship Systems I-Engineering

Fall: 9 units

A detailed study of ship characteristics and types including ship design, hydrodynamic forces, stability, compartmentalization, propulsion, electrical and auxiliary systems, interior communications, ship control, and damage control. Included are basic concepts of the theory and design of steam, gas turbine, internal combustion, and nuclear propulsion. Shipboard safety and firefighting are also discussed.

32-312 Naval Ship Systems II-Weapons

Spring: 9 units

This course outlines the theory and employment of weapons systems. The student explores the processes of detection, evaluation, threat analysis, weapon selection, delivery, guidance and explosives. Fire control systems and major weapon types are discussed, including capabilities and limitations. The physical aspects of radar and underwater sound are described in detail. The facets of command, control, and communications are explored as a means of weapons system integration.

32-400 Naval Laboratory

Fall and Spring: 3 units

Military drill, physical fitness, and leadership seminars.

32-402 Leadership and Ethics

Spring: 9 units

The study of naval junior officer responsibilities. The course exposes the student to a study of ethics, decision making and responsibility as well as counseling methods, military justice administration, naval human resources management, directives and correspondence, naval personnel administration, material management and maintenance and supply systems. This capstone course in the NROTC curriculum builds on and integrates the professional competencies developed in prior course work and professional training.

32-410 Amphibious Warfare/Operations & The Fundamentals of Maneuver Warfare

Fall: 9 units

A historical survey of the development of amphibious doctrine and the conduct of amphibious operations. Emphasis is placed on the evolution of amphibious warfare in the twentieth century, especially during World War II. Focus is applied to four main themes: political/strategic situation, sea-to-land transitions, tactics ashore, and development of amphibious technology. Present day potential and limitations on amphibious operations, including the rapid deployment force concept, are explored.

32-411 Naval Operations and Seamanship

Fall: 9 units

Designed as an introduction to naval operations and shipboard evolutions, vessel behavior and characteristics in maneuvering, applied aspects of ship handling, and afloat communications. This course builds upon the information presented in Navigation 32-212, Engineering 32-311, and Weapons Systems 32-312. An understanding of the nautical rules of the road, relative motion and vector analysis are utilized in discussion regarding the conduct of naval operation to include formation tactics and ship employment. The student will also be introduced to the various components of naval warfare and their role in sea control and power projection missions within naval and joint operations.

Degrees Offered

With cutting-edge brain science, path-breaking performances, innovative start-ups, driverless cars, big data, big ambitions, Nobel and Turing prizes, hands-on learning, and a whole lot of robots, CMU doesn't imagine the future, we create it. Carnegie Mellon offers a wide range of programs in seven schools and colleges, and has consistently ranked high in a number of disciplines (<https://www.cmu.edu/about/>).

To browse the primary degrees offered, select a school or college below. For a list of minors, please see Undergraduate Options (p. 22).

College of Engineering

Interdepartmental

- M.S. in Energy Science, Technology and Policy
- M.S. in Energy Science, Technology and Policy (Applied Studies)
- M.S. in Energy Science, Technology and Policy and Integrated Study in Computer Science
- M.S. in Engineering and Technology Innovation Management

Biomedical Engineering

- B.S. in an engineering discipline with an additional major in Biomedical Engineering (p. 77)
- M.S. in Biomedical Engineering
- M.S. in Biomedical Engineering and Integrated Study in Computer Science
- Ph.D. in Biomedical Engineering
- Ph.D. in Biomedical Engineering and Engineering and Public Policy

Chemical Engineering

- B.S. in Chemical Engineering (p.)
- M. of Chemical Engineering
- M. of Chemical Engineering & Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering
- M.S. in Chemical Engineering and Colloids, Polymers and Surfaces
- M.S. in Chemical Engineering and Integrated Study in Computer Science
- M.S. in Colloids, Polymers and Surfaces
- Ph.D. in Chemical Engineering

Civil and Environmental Engineering

- B.S. in Civil Engineering (p. 102)
- M.S. in Advanced Infrastructure Systems
- M.S. in Civil Engineering
- M.S. in Civil and Environmental Engineering
- M.S. in Civil & Environmental Engineering and Integrated Study in Computer Science
- M.S. in Civil and Environmental Engineering/M. of Business Administration (jointly with the Tepper School of Business)
- M.S. in Computational Mechanics
- M.S. in Environmental Engineering
- M.S. in Environmental Management and Science
- Ph.D. in Advanced Infrastructure Systems
- Ph.D. in Civil Engineering
- Ph.D. in Civil and Environmental Engineering
- Ph.D. in Civil and Environmental Engineering and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Computational Mechanics
- Ph.D. in Environmental Engineering
- Ph.D. in Environmental Management and Science

Electrical and Computer Engineering

- B.S. in Electrical and Computer Engineering (p. 115)
- B.S. in Music and Technology (jointly with the Department of Music and the School of Computer Science)
- M.S. in Electrical and Computer Engineering
- M.S. in Electrical & Computer Engineering and Integrated Study in Computer Science

- M.S. in Software Engineering (Silicon Valley Campus)
- Master of Science in Software Engineering - Development Management (Silicon Valley Campus)
- Ph.D. in Electrical and Computer Engineering

Engineering and Public Policy

- B.S. in an engineering discipline with an additional major in Engineering and Public Policy (p. 130)
- B.S. in CFA, DC, MCS, or SCS and an additional major in Science, Technology and Public Policy (p. 131)
- M.S. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy
- Ph.D. in Engineering and Public Policy and an engineering discipline
- Ph.D. in Engineering & Public Policy and Language & Information Technologies
- Ph.D. in Engineering and Public Policy and Statistics (jointly with the Department of Statistics)

Information and Communication Technology

- M.S. in Information Technology (CMU Africa campus only)

Information Networking Institute

- M.S. in Information Networking
- M.S. in Information Security
- M.S. in Information Technology - Information Security
- M.S. in Information Technology - Mobility
- M.S. in Information Technology - Software Management

Materials Science and Engineering

- B.S. in Materials Science and Engineering (p. 144)
- M.S. in Additive Manufacturing
- M.S. in Computational Materials Science and Engineering
- M.S. in Materials Science
- M.S. in Materials Science and Engineering
- M.S. in Materials Science & Engineering and Integrated Study in Computer Science
- Ph.D. in Materials Science
- Ph.D. in Materials Science and Engineering

Mechanical Engineering

- B.S. in Mechanical Engineering (p. 155)
- M.S. in Computational Design and Manufacturing
- M.S. in Mechanical Engineering
- M.S. in Mechanical Engineering - Advanced Study
- M.S. in Mechanical Engineering - Research
- Ph.D. in Mechanical Engineering

College of Fine Arts

Architecture

- B. of Architecture (p. 196) (5-year program)
- B.A. in Architecture
- M. of Advanced Architectural Design
- M. of Architecture
- M.S. in Architecture
- M.S. in Building Performance and Diagnostics
- M.S. in Computational Design
- M.S. in Sustainable Design
- M.S. in Sustainable Design (Advanced Studies)
- M.S. in Sustainable Design (Applied Studies)
- M. of Tangible Interaction Design
- M. of Urban Design
- D. of Professional Practice in Advanced Architectural Design
- D. of Professional Practice in Architecture

- Ph.D. in Architecture
- Ph.D. in Building Performance and Diagnostics
- Ph.D. in Computational Design

Art

- B.F.A. in Art (p. 224)
- M.F.A. in Art

Design

- B. of Design (p. 240)
- M.A. in Design
- M. of Design in Design for Interactions
- M. of Design in Interaction Design
- M. of Professional Studies in Design for Interactions
- D. of Design
- Ph.D. in Communication De
- Ph.D. in Design

Drama

- B.F.A. in Drama (p. 258)
- M.F.A. in Costume Design
- M.F.A. in Costume Production
- M.F.A. in Directing
- M.F.A. in Dramatic Writing
- M.F.A. in Lighting Design
- M.F.A. in Scene Design
- M.F.A. in Sound Design
- M.F.A. in Stage and Production Management
- M.F.A. in Technical Direction
- M.F.A. in Video and Media Design

Music

- B.F.A. in Music (Composition) (p. 291)
- B.F.A. in Music Performance (p. 291) (various disciplines)
- B.S. in Music and Technology (p. 296) (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)
- M. Music in Composition
- M. Music in Music Education
- M. Music in Performance (various disciplines)
- M.S. in Music and Technology (jointly with the Department of Electrical and Computer Engineering and the School of Computer Science)

Dietrich College of Humanities and Social Sciences

Interdepartmental

- B.A./B.S. in Ethics, History, and Public Policy (p. 559) (jointly offered by the Departments of History and Philosophy)
- B.S. in Information Systems (p. 409)
- B.A. in Linguistics (p. 560) (jointly offered by the Departments of English, Modern Languages, Philosophy, and Psychology)
- B.S. in Neuroscience (p. 890) (jointly offered by the Department of Biological Sciences and the Center for the Neural Basis of Cognition)
- B.S. in Psychology and Biological Sciences (p. 561) (jointly offered by the Departments of Psychology and Biological Sciences)
- B.S. in Statistics and Machine Learning (p. 543) (jointly offered by the Department of Statistics and Data Science and the School of Computer Science)

CARNEGIE MELLON INSTITUTE FOR SECURITY AND TECHNOLOGY

- B.S. in Economics and Politics (p.)

Center for the Neural Basis of Cognition

- Ph.D. in Neural Computation
- Ph.D. in Neural Computation and Machine Learning
- Ph.D. in Neural Computation and Statistics

English

- B.A. in Creative Writing (p. 335)
- B.A. in Film and Visual Media (p. 336)
- B.A. in Literature and Culture (p. 338)
- B.A. in Professional Writing (p. 340)
- B.S. in Technical Writing (p. 341)
- M.A. in Global Communication and Applied Translation
- M.A. in Literary and Cultural Studies
- M.A. in Professional Writing
- M.A. in Rhetoric
- Ph.D. in Literary and Cultural Studies
- Ph.D. in Rhetoric

History

- B.A. in Global Studies (p. 385)
- B.A./B.S. in Social and Political History (p. 382)
- M.A. in History
- Ph.D. in History

Modern Languages

- B.A. in Chinese Studies (p. 435)
- B.A. in French and Francophone Studies (p. 437)
- B.A. in German Studies (p. 438)
- B.A. in Hispanic Studies (p. 439)
- B.A. in Japanese Studies (p. 441)
- B.A. in Russian Studies (p. 442)
- M.A. in Applied Second Language Acquisition
- M.A. in Second Language Acquisition
- Ph.D. in Second Language Acquisition

Philosophy

- B.A. in Philosophy (p. 479)
- B.S. in Logic and Computation (p. 478)
- M.A. in Philosophy
- M.S. in Logic, Computation and Methodology
- Ph.D. in Logic, Computation and Methodology
- Ph.D. in Philosophy
- Ph.D. in Pure and Applied Logic

Politics and Strategy

- B.S. in International Relations and Politics (p. 417)
- M.S. in International Relations and Politics

Psychology

- B.A./B.S. in Psychology (p. 496)
- B.S. in Cognitive Science (p. 500)
- Ph.D. in Cognitive Neuroscience
- Ph.D. in Psychology
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Social and Decision Sciences)

Social and Decision Sciences

- B.S. in Behavioral Economics (p. 515)
- B.S. in Decision Science (p. 517)
- B.S. in Policy and Management (p. 518)
- M.S. in Behavioral Decision Research
- M.S. in Social and Decision Sciences
- Ph.D. in Behavioral Decision Research
- Ph.D. in Behavioral Economics (jointly with Tepper School of Business)
- Ph.D. in Behavioral Marketing and Decision Research (jointly with Tepper School of Business)
- Ph.D. in Psychology and Behavioral Decision Research (jointly with the Department of Psychology)
- Ph.D. in Social and Decision Sciences

Statistics and Data Science

- B.S. in Statistics (p. 531)
- B.S. in Statistics (Mathematical Sciences Track) (p. 534)
- B.S. in Statistics (Statistics and Neuroscience Track) (p. 537)
- B.S. in Statistics and Machine Learning (p.) (jointly with the School of Computer Science)
- B.S. in Economics and Statistics (p. 556)
- M. of Statistical Practices
- Ph.D. in Neural Cognition and Statistics (jointly with the Center for the Neural Basis of Cognition)
- Ph.D. in Statistics
- Ph.D. in Statistics and Engineering and Public Policy (jointly with the Department of Engineering and Public Policy)
- Ph.D. in Statistics and Machine Learning (jointly with the Department of Machine Learning)
- Ph.D. in Statistics and Public Policy (jointly with the Heinz College)

H. John Heinz III College

School of Information Systems & Management

Information Security

- M.S. in Information Security Policy and Management

Information Systems

- M. of Information Systems Management
- M. of Information Systems Management in Business Intelligence and Data Analytics
- Ph.D. in Information Systems and Management

Information Technology

- M.S. in Information Technology (Business Intelligence and Data Analytics)
- M.S. in Information Technology (IT Management)
- M.S. in Information Technology (Information Security and Assurance)
- M.S. in Information Technology (Software Design and Management)

School of Public Policy & Management

Arts Management

- M. of Arts Management (jointly with the College of Fine Arts)
- M. of Arts Management (jointly with the College of Fine Arts) and Graduate Degree in Innovation and Organization of Culture and the Arts (jointly with the University of Bologna's School of Economics)
- M. of Arts Management (jointly with the College of Fine Arts) and J.D. (jointly with the University of Pittsburgh School of Law)

Entertainment Industry Management

- M. of Entertainment Industry Management (jointly with the College of Fine Arts)

Health Care Policy and Management

- M.S. in Health Care Analytics and Information Technology
- M.S. in Health Care Policy and Management
- M.S. in Health Care Policy and Management and M.B.A. (jointly with Tepper School of Business)

Medical Management

- M. of Medical Management

Public Management

- M. of Public Management

Public Policy and Management

- M.S. in Public Policy and Management
- M.S. in Public Policy and Management (Data Analytics)
- M.S. in Public Policy and Management and M.B.A. (jointly with Tepper School of Business)

- M.S. in Public Policy and Management and J.D. (jointly with the University of Pittsburgh School of Law)
- M.S. in Public Policy and Management and M. of Divinity (jointly with the Pittsburgh Theological Seminary)
- Ph.D. in Economics and Public Policy (jointly with the Tepper School of Business)
- Ph.D. in Machine Learning and Public Policy (jointly with the School of Computer Science)
- Ph.D. in Public Policy and Management
- Ph.D. in Statistics and Public Policy (jointly with Dietrich College of Humanities and Social Sciences)

Adelaide, South Australia Campus

- M.S. in Information Technology
- M.S. in Public Policy and Management

Mellon College of Science

Interdepartmental

- B.S. in Mathematical Sciences and Economics (jointly offered by the Department of Mathematical Sciences and the Undergraduate Economics Program)
- Ph.D. in Molecular Biophysics and Structural Biology

Biological Sciences

- B.A. in Biological Sciences (p. 593)
- B.S. in Biological Sciences (p. 590)
- B.S. in Biological Sciences/Neuroscience Track (p. 592)
- B.S. in Biological Sciences and Psychology (p. 593) (jointly with the Department of Psychology)
- B.S. in Neuroscience (p. 592) (jointly with the Department of Psychology)
- M.S. in Biological Sciences
- Ph.D. in Biological Sciences

Chemistry

- B.A. in Chemistry (p. 610)
- B.S. in Chemistry (p. 607)
- B.S. in Chemistry/Biological Chemistry Track (p. 612)
- M.S. in Chemistry
- M.S. in Colloids, Polymers, and Surfaces (jointly with the Department of Chemical Engineering)
- Ph.D. in Chemistry

Mathematical Sciences

- B.S. in Mathematical Sciences (p. 637)
- M.S. in Algorithms, Combinatorics, and Optimization
- M.S. in Mathematical Sciences
- M.S. in Computational Finance (jointly with the Department of Statistics, the H. John Heinz III College, and the Tepper School of Business)
- D.A. in Mathematical Sciences
- Ph.D. in Algorithms, Combinatorics, and Optimization
- Ph.D. in Mathematical Finance
- Ph.D. in Mathematical Sciences
- Ph.D. in Pure and Applied Logic (jointly with the Department of Philosophy and the School of Computer Science)

Physics

- B.A. in Physics (p. 661)
- B.S. in Physics (p. 659)
- M.S. in Physics
- Ph.D. in Applied Physics
- Ph.D. in Physics

School of Computer Science

ARTIFICIAL INTELLIGENCE

- B.S. in Artificial Intelligence (p. 689)

Computer Science

- B.S. in Computer Science (p. 698) (jointly with the Institute for Software Research)
- B.S. in Music and Technology (p. 296) (jointly with the Departments of Electrical and Computer Engineering and Music)
- M.S. in Computer Science
- M.S. in Computer Science - Foundational Studies
- M.S. in Computer Science - Research
- M.S. in Computer Science - Research Thesis
- M.S. in Computer Science (5th Year Scholars Program only)
- Ph.D. in Algorithms, Combinatorics and Optimization (jointly with the Department of Mathematical Sciences and Tepper School of Business)
- Ph.D. in Computer Science
- Ph.D. in Pure and Applied Logic (jointly with the Department of Mathematical Sciences and the Department of Philosophy)

Computational Biology Department

- B.S. in Computational Biology (p. 694)
- M.S. in Automated Science - Biological Experimentation
- M.S. in Computational Biology
- Ph.D. in Computational Biology

Human-Computer Interaction

- B.S. in Human-Computer Interaction (p. 703)
- M. of Human-Computer Interaction
- M. of Human-Computer Interaction (5th Year Scholars Program only)
- M. of Educational Technology & Applied Learning Sciences (jointly with the Dietrich College of Humanities and Social Sciences)
- M.S. in Product Management (jointly with Tepper School of Business)
- Ph.D. in Human-Computer Interaction

Institute for Software Research

- M. of Software Engineering in Embedded Systems
- M. of Software Engineering in Scalable Systems
- M. of Software Engineering in Software Engineering
- M.S. in Information Technology - Privacy Engineering
- Ph.D. in Societal Computing
- Ph.D. in Software Engineering

Language Technologies Institute

- M.S. in Artificial Intelligence and Innovation
- M.S. in Intelligent Information Systems
- M.S. in Intelligent Information Systems - Advanced Study
- M.S. in Language Technologies
- M. of Computational Data Science
- Ph.D. in Language and Information Technologies

Machine Learning

- M.S. in Machine Learning
- M.S. in Machine Learning (5th Year Scholars Program only)
- Ph.D. in Machine Learning
- Ph.D. in Machine Learning & Public Policy (jointly with the Heinz College)
- Ph.D. in Neural Computation and Machine Learning (jointly with Center for Neural Basis of Cognition)
- Ph.D. in Statistics and Machine Learning (jointly with the Dietrich College of Humanities and Social Sciences)

Robotics Institute

- B.S. in Robotics (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/robotics/>)
- M.S. in Computer Vision
- M.S. in Robotics
- M.S. in Robotics (5th Year Scholars Program only)
- M.S. in Robotic Systems Development
- Ph.D. in Robotics

David A. Tepper School of Business

Business Administration

- B.S. in Business Administration (p. 841)

Economics

- B.A. in Economics (p. 865)
- B.S. in Economics (p. 866)
- B.S. in Economics and Mathematical Sciences (p. 866)

Industrial Administration

- M. of Business Administration (M.B.A.)
- M.B.A./M.S. in Public Policy Management (jointly with Heinz College)
- M.B.A./M.S. in Civil and Environmental Engineering (in association with Carnegie Institute of Technology)
- M.B.A. and J.D. in Law (jointly with the University of Pittsburgh Law School)
- M.B.A./M.S. in Health Care Policy Management (jointly with Heinz College)
- M.B.A./M.S. in Software Engineering (jointly with the School of Computer Science)
- M.S. in Business Analytics
- M.S. in Computational Finance (jointly with Dietrich College, the Mellon College of Science, and Heinz College)
- M.S. in Product Management
- Ph.D. in Accounting
- Ph.D. in Algorithms, Combinatorics, and Optimization (jointly with the School of Computer Science and Department of Mathematical Sciences)
- Ph.D. in Economics
- Ph.D. in Finance
- Ph.D. in Information Systems
- Ph.D. in Management of Manufacturing and Automation (with Robotics Institute)
- Ph.D. in Marketing
- Ph.D. in Operations Management and Manufacturing
- Ph.D. in Operations Research
- Ph.D. in Organizational Behavior and Theory
- Ph.D. in Economics and Public Policy (jointly with Heinz College)
- Ph.D. in Strategy, Entrepreneurship, and Technological Change (jointly with the Department of Social and Decision Sciences, Heinz College, and the Department of Engineering and Public Policy)

University-Wide, Interdisciplinary, and Joint Degree Programs

Architecture-Engineering-Construction Management Program

- M.S. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)
- Ph.D. in Architecture-Engineering-Construction Management (jointly with the Department of Civil and Environmental Engineering and the School of Architecture)

BXA Intercollege Degree Programs

- B. of Computer Science and Arts (p.) (jointly with the School of Computer Science and the College of Fine Arts)
- B. of Engineering Studies and Arts (p. 897) (jointly with the College of Engineering and the College of Fine Arts)
- B. of Humanities and Arts (p.) (jointly with the Dietrich College of Humanities and Social Sciences and the College of Fine Arts)
- B. of Science and Arts (p.) (jointly with the Mellon College of Science and the College of Fine Arts)
- B.S. in an engineering discipline with an additional major in Engineering and Arts (p. 932) (jointly with the College of Engineering and College of Fine Arts)

Communication Planning and Information Design Program

- M. Design in Communication Planning and Information Design (jointly with the School of Design and the Department of English)

Computational Finance Program

- B.S. in Computational Finance (p. 880) (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)
- M.S. in Computational Finance (jointly with the Dietrich College of Humanities and Social Sciences, Heinz College, Mellon College of Science and Tepper School of Business)

Entertainment Technology Center

- M. of Entertainment Technology

information technology strategy

- M.S. in Information Technology Strategy (MITS) (<https://www.cmu.edu/mits/>) (jointly with the College of Engineering, School of Computer Science and Institute for Politics and Strategy)

Integrated Innovation Institute

- M. of Integrated Innovation for Products and Services
- M. of Integrated Innovation for Products and Services - Advanced Study
- M.S. in Software Management (Silicon Valley campus)

Science and Humanities Scholars Program

- B.A./B.S. in various disciplines (p.) (jointly with the Dietrich College of Humanities and Social Sciences and the Mellon College of Science)

Carnegie Mellon University in Qatar

Qatar Biological Sciences

- B.S. in Biological Sciences

Qatar Business Administration

- B.S. in Business Administration

Qatar Computer Science

- B.S. in Computer Science
- B.S. in Computational Biology

Qatar Information Systems

- B.S. in Information Systems

Schools/Colleges

The intersection of fields is a Carnegie Mellon University specialty. Renowned faculty at the university's seven schools/colleges explore side by side with students, collaborating on research, tackling society's biggest challenges and delivering work that matters. In addition to the hundreds of programs offered by the schools and colleges, CMU also offers dozens of interdisciplinary programs (p. 880), which are designed especially for students who want to work beyond just one discipline.

College of Engineering

William H. Sanders, Dr. William D. and Nancy W. Strecker Dean of the College of Engineering & Professor, Electrical and Computer Engineering

Conrad Zapanta Ph.D, Associate Dean for Undergraduate Studies and Teaching Professor in Biomedical Engineering

Kurt Larsen, Assistant Dean for Undergraduate Studies

Treci Bonime, Assistant Dean for Undergraduate Studies

Location: ANSYS Hall, 2nd floor
<https://engineering.cmu.edu>

Carnegie Institute of Technology (CIT), the engineering college of the university, has three main activities - undergraduate education, graduate education, and research. Its continuing goal has been to maintain excellence in all these activities. The degree to which this goal has been achieved is attested to by the demand for its graduates, the success of its alumni, the quality of its students and faculty, the adoption elsewhere of its innovations, and the national and international recognition it receives in educational and research activities.

The college offers the degree of bachelor of science in chemical engineering, civil engineering, electrical and computer engineering, mechanical engineering, and materials science and engineering. All of these programs are accredited by ABET, www.abet.org (<http://www.abet.org>).

An engineering student may also choose to pursue a minor in one of the CIT designated minor programs, or a double major in engineering and public policy, biomedical engineering or engineering design, innovation & entrepreneurship, or to design a minor, additional major or dual-degree programs with other non-engineering departments.

Educational Objectives

The overarching objective of our engineering curriculum is to provide our students an education that enables them to be productive and fulfilled professionals throughout their careers. Our more specific, measurable objectives for graduates of our engineering curriculum are the following:

- Graduates recognize that they acquired a high quality, rigorous technical education from the College of Engineering at Carnegie Mellon.
- Graduates, in addition to their technical knowledge, recognize that they have acquired a broader body of knowledge that allows them to understand the larger context of the problems that they must address during their career.
- Graduates use their technical foundation and their broader base of knowledge to be successful in a diverse collection of individual careers inside and outside of the engineering profession.

From its earliest days, Carnegie Institute of Technology (CIT) has considered undergraduate education to be the key element in the development of future leaders. In this regard, CIT has adopted a plan for education that is designed to equip students with the capacity to learn and to continue the process of self-education throughout their lives. The present curriculum incorporates this philosophy by providing the opportunity for both breadth in a number of engineering, science, humanities and fine arts areas as well as depth in a major area of concentration. To achieve these goals, our flexible curriculum has been designed to allow students to customize their program to suit their needs and to help each student acquire:

- A thorough and integrated understanding of fundamental knowledge in fields of a students' major interest and the ability to use this knowledge;
- Competence in the orderly way of thinking, which professionals and scientists have always used in reaching sound, creative conclusions, with the goal that after graduation the student can, by such thinking, reach decisions both as a professional and as a citizen;
- An ability to learn independently with scholarly orderliness, so that after graduation the student will be able to grow in wisdom and keep abreast of the changing knowledge and problems of the profession and the society in which he or she participates;
- The philosophical outlook, breadth of knowledge, and sense of values which will increase the student's understanding and enjoyment of life and enable each student to recognize and deal effectively with the human, economic, ethical and social aspects of professional problems; and

- The ability to communicate ideas to others in a comprehensive and understandable manner.

The curriculum encourages students to confront professional problems, accomplished through team and problem-oriented courses, as well as courses which emphasize design or individual projects. These classes stress creativity and independent thought and require the student to define the problem, propose a solution or a design in the presence of technical and socioeconomic constraints, to make judgments among alternative solutions, and to explore innovative alternatives to more conventional solutions.

First Year for Engineering Students

The Carnegie Mellon engineering education is based on engineering and science fundamentals that give students the skills to face new and challenging situations. The first year in engineering provides a broad foundation upon which students build a curriculum in their eventual major.

Since students in CIT do not select a major until the end of the first year, all first year students share a common experience consisting of introductory courses in the engineering majors (one each semester), calculus, physics, other science courses which complements specific introductory engineering courses, and courses in the liberal arts, fine arts, business, and social sciences. This curriculum helps make an informed decision about a final major. Below is an examples of a standard schedule for a first-year engineering student.

| | |
|--|------|
| Fall Semester | |
| Introductory Engineering Elective | 12 |
| Restricted Technical Elective | 9-12 |
| Differential and Integral Calculus | 10 |
| General Education | 9 |
| Computing @ Carnegie Mellon | 3 |
| Spring semester | |
| Introductory Engineering Elective | 12 |
| Restricted Technical Elective | 10 |
| Integration, Differential Equations, Approximation | 10 |
| General Education Course | 9 |

Notes:

1. Each semester every CIT department offers its Introductory Engineering Elective. Every first year CIT student must select one such course each semester.
2. Each Introductory Engineering Elective requires a specific Restricted Technical Elective as given below. Restricted Technical Electives are foundational science courses relevant to engineering degrees.

| Introductory Engineering Course | Restricted Technical Elective |
|-----------------------------------|-------------------------------|
| Biomedical Engineering | 03-121 |
| Chemical Engineering | 09-105 |
| Civil & Environmental Engineering | 33-141 |
| Electrical & Computer Engineering | 15-110 or 15-112 |
| Engineering & Public Policy | 33-141 |
| Mechanical Engineering | 33-141 |
| Materials Science & Engineering | 33-141 |

3. All students must complete 33-141 Physics I for Engineering Students by the end of the first year. Therefore, if a student chooses to take Introduction to Chemical Engineering (with 09-105 as a co-requisite) during one semester and Introduction to Electrical and Computer Engineering (with 15-110 as a co-requisite), the student must take 33-141 in place of the General Education requirement in the Spring semester of the first year and take the General Education course in a subsequent semester. Alternatively, a student entering the university with AP credit in a required first year course may substitute 33-141 in its place.
4. CIT students must complete the First-Year Writing requirement in their freshman year. View more information (p. 71).

General Education Programs

The environment in which today's engineering graduates will find themselves working is evolving rapidly. Technical innovation is becoming ever more critical to retaining a competitive edge. This is true for individuals, for firms and for nations. Start-ups, as well as established companies, have significant international opportunities but also face more competition in a global economy. Seizing these opportunities and dealing with the associated challenges requires an understanding of the global context in which engineers work, as well as understanding multi-disciplinary approaches to technological innovation across cultures.

The College of Engineering has developed General Education Requirements designed to ensure that our students are ready to work effectively in the global economy, and become the innovators and leaders of tomorrow.

CIT General Education Requirements

All undergraduate students must complete the First-Year Writing requirement — **the Department of English does not accept any Advanced Placement exemptions.** This requirement can be completed in two different ways:

Option 1: Enroll in one of two full-semester courses (9 units each)

76-101 Interpretation and Argument (Students for whom English is a second language may need to take 76-100 Reading and Writing in an Academic Context first. The English department will contact those students.)

76-102 Advanced First Year Writing: Special Topics: (by invitation only)

Option 2: Enroll in two of three half-semester "mini" courses* (4.5 units each)

76-106 Writing about Literature, Art and Culture:

76-107 Writing about Data

76-108 Writing about Public Problems

*Minis should be completed back-to-back within a single semester.

General Education Electives (3 total)

At least 27 units from any non-technical academic courses from the Dietrich College, College of Fine Arts, and the Tepper School of Business excluding those listed on the General Education Exclusions page (<https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/exclusions.html>). Courses from this list of non-technical courses outside of the Dietrich College or the College of Fine Arts (<https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/non-dietrich-cfa-courses.html#undefined>) may also be counted. **A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit.**

For category course lists reference the CIT General Education website (<https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/>).

General Education Categories

Students must complete each of the categories (descriptions of categories follow below). This is a 9-unit requirement. Any course taken on this list that is below 9 units must be combined with an additional course to total at least 9 units in order to complete this requirement.

Note that the units from one course cannot be split to count for two General Education categories (eg PPC and General Education Elective).

- **Innovation & Internationalization (I&I)**
 - 9 units from the I&I list of courses (which could be two 4.5 unit courses);
- **Peoples, Places, and Cultures (PPC)** ¹
 - 9 units from the PPC list; (Students can receive exemption through an approved study abroad program. These students would have three General Education Electives to complete instead of two.)
- **Social Analysis and Decision Making (SDM)**
 - 9 units from the SDM list of courses (which could be two 4.5 unit courses)
- **Writing and Expression (W&E)**
 - 9 units from the W&E list of courses (in addition to 76-101)

Experiential Learning (EL)

- 6 EL points by participating in a variety of approved activities in the following timeframe:
 - 2 points sophomore fall semester (39-210)
 - 2 points sophomore spring semester (39-220)
 - 2 points junior fall semester (39-310)

Category Descriptions

People, Places and Cultures (PPC)

PPC courses are designed to help you gain better understanding of the diversity of the world in which we live, and the way in which societal factors interact to shape that world.

Social Analysis and Decision Making (SDM)

SDM courses are focused on helping you to gain an understanding of different ways in which individuals and societies approach and make decisions.

Innovation and Internationalization (I&I)

I&I courses are intended to provide a broad perspective regarding the creation of pioneering ideas and their outcomes in a global context.

Experiential Learning (EL)

Being curious and constantly looking for inspiration are critical parts of lifelong learning. To be successful as an engineer and as a citizen, your education must not stop when you graduate from Carnegie Mellon. The EL requirement aims to encourage a habit of lifelong learning about innovation and the growing internationalization in engineering and, indeed of many other aspects of the modern world. The goal of this requirement is to help inspire the habits of being open to new ideas as successful, innovative engineers.

To do that, during both semesters of your sophomore year, and the first semester of your junior year, we require you to choose a few related activities that are not part of your formal course work. Examples could include:

- Attending approved seminars and then submitting a one page write up of your thoughts on what you heard;
- Holding an official leadership position (i.e., President, Vice President, Secretary, Treasurer) in a Carnegie Mellon sponsored organization

Additional Majors, Dual Degrees & Minors

A major is defined as a program that must be completed for the granting of a degree. Additional majors comprise a single degree with majors in two separate areas; for example, the degree of Bachelor of Science in Chemical Engineering and an additional major in English. Although the additional major requires the completion of two designated programs, they may have overlapping requirements that can be met simultaneously. The general principle used to measure eligibility for a College of Engineering additional major is that the major (core) requirements of both departments must be completed. Finally, although the student is formally enrolled as an undergraduate in one of the departments (the parent department, which is responsible for scheduling and other administrative actions for the student), the student should apply for the additional major through the second department and coordinate requirements with both departments.

The additional major is to be distinguished from a dual degree program, which results in two separate bachelor's degrees; for example, Bachelor of Science in Chemical Engineering and a Bachelor of Arts in English. The dual degree, though, requires a minimum of 90 units of work in addition to the units required for the first degree. The second degree may be earned in Bachelor of Science or Bachelor of Arts degree programs.

Requirements for students wishing to complete Additional Majors in CIT

Note: This applies to all students.

The student must satisfactorily pass all requirements of the regular and complete program (with the permissible exceptions) leading to a degree in CIT. The minimum number of units required for the additional major is the number required by the parent department or major.

The student takes and satisfactorily completes the courses specified by a second department, usually using elective space available in the first program.

The second department, on the basis of the specified number of courses plus the courses comprising the parent department's regular degree requirements, then certifies that the student has completed the requirements for a major in the second department.

Equivalent technical electives may be substituted at the discretion of the departments/colleges.

Non-technical courses in the curricula can be used to meet the requirements of the second major. But if the second major is not a Dietrich College department, the program must include a minimum of 72 units of General Education courses to meet CIT requirements for graduation.

Bachelor of Engineering Studies and Arts (BESA Program)

The Bachelor of Engineering Studies and Arts (BESA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This degree is tailored for students seeking to apply knowledge from dual fields to advance maker culture in novel and creative ways. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their engineering studies concentration established by the College of Engineering. Options within the concentration include: biomedical engineering, chemical engineering, civil & environmental engineering, electrical & computer engineering, materials science & engineering or mechanical engineering.

The BESA curriculum has three main components: general education requirements, fine arts concentration requirements and engineering studies concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and ENG. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in ENG to guide their focus in engineering studies. Please reference the Internal Transfer (<https://www.cmu.edu/interdisciplinary/apply/internal-transfer.html>) process.

Engineering and Arts Additional Major

The Engineering and Arts (EA) additional major is intended for College of Engineering students who also have interest and talent in an arts concentration (architecture, art, drama or music) and goals that can only be accomplished at the intersection of those disciplines.

EA applications are considered every semester, with a deadline of mid-semester break for admission in the following semester. (See below for exceptions.) Along with the application, our additional major committee also considers prior semester grades and mid-semester grades for the semester of application. Decisions are sent out in advance of registration for the following semester.

The application includes an Essay of Interdisciplinary Intent, in which a student explains why they're interested in the two areas and why they want to combine them. This essay should be brief—500 words or fewer—and specific about both a student's background in the concentration areas and what their goals are for bringing them together.

Completing an additional major demands advanced planning and preparation to determine the most appropriate semester to take requirements. All students applying for EA must meet with their current Engineering advisor, the BXA director and an advisor in their target CFA area, as well as take preliminary coursework in their target area before submitting the application (<https://www.cmu.edu/interdisciplinary/apply/additional-major.html>).

Engineering, Design, Innovation, and Entrepreneurship Additional Major (EDIE Program)

Overview

As humanity grapples with dilemmas of extraordinary complexity throughout the globe, our world needs engineers who are leaders and change makers. Our world needs engineers who seek to push the boundaries in their education, and carry their passion for technological innovation forward.

The Engineering Design, Innovation, and Entrepreneurship (EDIE) additional major will provide students the know-how to innovate products around that technology and deliver product solutions to the people who need them.

EDIE students will have expertise in technology and the ability to design, develop, and deliver economically viable solutions to the real-world challenges of today and tomorrow.

Curriculum Details

The EDIE additional major isn't just for students who want to create a startup—it will help to prepare hands-on, get-it-done leaders who are in demand in all sectors of society and industry, for-profit and not-for-profit. Given the applied focus of our curriculum, courses will equip our students with mindsets, skills, and capabilities to identify and shape opportunities and develop economically sustainable solutions.

Students in the EDIE additional major must also satisfy the core requirements of their primary major typically following the standard schedule of courses each semester. EDIE core requirements are fulfilled in addition to the course requirements of their primary major, mainly using various elective units. The side-by-side curriculum charts for each primary major show how the requirements for the stand-alone majors and the primary major plus EDIE additional major compare.

Course Requirements

Introductory Course
49-101 Engineering Design, Innovation and Entrepreneurship (12 units)

Engineering Design and Innovation Courses
49-305 Customer Discovery for Tech Innovation (4.5 units)
49-306 Engineering Design Methods & Tools (4.5 units)
49-405 Leading Engineering Innovation Teams (4.5 units)

Engineering Entrepreneurship Courses
49-205 Tech Venture Marketing for Engineers (4.5 units)
49-206 Tech Business Planning (4.5 units)
49-406 Tech Venture Formation (4.5 units)

Foundation Skills Courses
73-102 Principles of Microeconomics (9 units)
70-345 Business Presentations (9 units)

Home Department Engineering Design Capstone (12 units)

Please consult with your home engineering department to confirm the specific Engineering Design Capstone course(s) that apply to your primary engineering degree. 12 units will count towards your EDIE degree requirements.

49-420 EDIE Innovation Capstone Course (9 units)
49-421 EDIE Entrepreneurship Capstone Course (9 units)

Designated Minors for Engineering Students

Undergraduate students in the College of Engineering can elect to complete an interdisciplinary Designated Minor in addition to their primary major. Designated minors have been added to the curriculum to provide the student with technical elective content in areas related to the research expertise of our faculty. Students may select a designated minor from the following list:

- Audio Engineering
- Biomedical Engineering*
- Colloids, Polymers and Surfaces
- Electronic Materials
- Global Engineering
- Information Security, Privacy, and Policy*
- Material Science and Engineering
- Mechanical Behavior of Materials

* Also available for non-CIT students

Complete descriptions of the designated minors can be found at CIT Designated Minors (<http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/undergraduatedesignatedminors/.html>).

To declare a CIT Designated Minor, please contact the director listed for each minor.

Minors for Non-Engineering Students

Students in a non-engineering discipline can also declare certain CIT minors:

- Biomedical Engineering
- Engineering Studies
- Technology and Policy

A full listing of curriculum for these minors when taken by non-engineering students can be found at CIT Minors for Non-Engineering Students (p. 173).

Academic Standards

Grading Practices

For undergraduate grading regulations, please see Undergraduate Academic Regulations (p. 25).

CIT Dean's Honor List

Each semester, Carnegie Institute of Technology recognizes students who have earned outstanding academic records by naming them on the dean's honor list. The criterion for such recognition is a semester quality point average of at least 3.75 while completing at least 36 factorable units and earning no incomplete grades.

Transfer into CIT Departments

Undergraduate students admitted to colleges other than CIT who wish to transfer into a CIT department during their first year should consult with an advisor in the Undergraduate Studies Office in the CIT Dean's Office. Students admitted to CIT but excluded from certain departments must also consult with the CIT Dean's Office if they wish to transfer into a restricted CIT department.

First-year students can apply for transfer after mid-semester grades for the spring semester have been posted. At that time, a decision will be based on availability of space and the student's academic performance.

CIT undergraduate students beyond the first year wishing to transfer into another CIT department may apply if they are in good academic standing and if there is room in the department of their choice. If the demand for any department exceeds the space available, then the department will admit students based on a comparative evaluation of all applicants at the end of each semester, up to the limit of available space.

Undergraduate students not in CIT who wish to transfer into a CIT department beyond the first year will be considered for transfer on a rolling space available/academic performance basis.

Criteria for all applicants include space in the department, good academic standing, and successful completion of or being currently enrolled in at least one introductory to engineering course (minimally the one of the target major), the appropriate science co-requisite, math (21-120, 21-122) and Physics 1 (33-141, 33-121, or 33-151).

Procedure for transfer of students from another university into CIT departments: A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student's record is sent to the CIT Undergraduate Studies Office for evaluation and a decision on acceptance/rejection is made in consultation with the target department.

Academic Actions

In order to maintain good academic standing, CIT students must attain at least minimum quality point averages for each semester (as well as cumulatively) and also maintain adequate progress toward completing graduation requirements. Minimum quality point averages for good academic standing are 1.75 each semester in the freshman year and 2.00 thereafter. "Adequate academic progress towards graduation" generally means that students are successfully completing approximately 45-55 units per semester so that at the end of eight semesters they will have accumulated the minimum units required for graduation, have a cumulative QPA of at least 2.00, and have completed all degree requirements.

When a student fails to meet minimum performance criteria, it normally results in an academic action. Depending on the circumstances, one of the following actions is taken: academic probation, continued probation, suspension, or drop. These academic actions are recommended by the college's departments, based on the guidelines described below, and adjudicated by the CIT Undergraduate Studies Office. However, the sequence of the academic actions is not automatic in all cases. Decisions may be based on unique individual student performance and circumstances, and are not determined solely on the basis of grades and quality point averages.

Probation

A student is on academic probation when performance either for the semester or cumulatively fails to meet the minimum standard. The term of academic probation is one semester, and signifies to the student the college's insistence that academic performance return to at least the minimum acceptable level.

Students are removed from probation when adequate academic progress* toward completing graduation requirements is being made, and:

- First year students: if the second semester's QPA and fall/spring combined QPA is 1.75 or above
- Students in the third or subsequent semester of study: if the semester QPA and cumulative QPA (excluding the first year) are 2.00 or above"

A first-year student who earns fewer than 27 units per semester, or who has a semester grade point average below 1.75 for either the first or second semester will be placed on academic probation*.

A student in the third or subsequent semester, who earns fewer than 27 units per semester or fewer than 108 units over three consecutive semesters (excluding summers) or who has a semester grade point average below 2.00 will be placed on academic probation*.

Probation Continued

A student who is currently on probation but whose record indicates that the standards are likely to be met by the end of the next semester may be continued on probation at the discretion of the associate dean.

Suspension

A first year student on probation, who earns a semester grade point average below 1.75 or completes less than 27 units for that probationary semester will be suspended*.

A student on probation in the third or subsequent semester, who earns a semester grade point average below 2.00, fewer than 27 units per semester for that probationary semester or fewer than 108 units over the last three consecutive semesters (excluding summers) will be suspended*.

The typical period of academic suspension is two semesters, during which a student on academic suspension is expected to reflect on the circumstances leading up to the suspension, identify the issues that prevented achieving academic success, take actions that address these issues, demonstrate sufficient readiness to return to the university and successfully resume his or her studies.

Two months prior to the end of that suspension period, a student may petition to return to school (on probation) by completing the following steps:

- Writing a formal petition, requesting to return and receiving permission in writing from the CIT associate dean for undergraduate studies.
- Completing a Return from Leave of Absence form from Enrollment Services; and
- Providing transcripts and clearance forms if the student has been in a program at another college or university even though academic credit earned may not transfer back to Carnegie Mellon unless prior approval from the Associate/Assistant Dean is given.

Drop

The most severe academic action occurs when a student is dropped from the college, and is not permitted to re-enroll. This normally results when a student, already on final academic probation, continues to perform at levels below the minimum set by the college for good academic standing, and does not show indication of being able to reach an acceptable level of performance or maintain adequate academic progress toward completing graduation requirements. It is also an option when, in unusual cases, a student has performed poorly, and has been unresponsive to outreach efforts by college and/or university offices seeking to offer help and support.

*Note: students with accommodations approved by the Office of Disability Resources, the Counseling and Psychological Services Center or the Dean of Student Affairs may petition for an exception to adequate academic progress rules.

Students who are suspended, dropped, take a leave of absence or withdraw are required to vacate the campus (including residence halls and Greek houses) within a maximum of two days after the action and to remain off the campus for the duration of the time specified. This action includes debarment from part-time or summer courses at the university for the duration of the period of the action.

Graduation Requirements and degree certification

To be eligible to graduate, undergraduate students must complete all course requirements for their department with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students

who enrolled at Carnegie Mellon as freshman and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some departments may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

1. All mathematics (21-xxx) courses **required*** for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

***Elective mathematics courses are not included in this policy**

Students must be recommended for a degree by the faculty of CIT.

A candidate must meet the residence requirement of having completed at least 180 units at Carnegie Mellon University.

Students must meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may seek permission to modify graduation requirements by petition to the CIT College Council.

Please reference the University's Degree Certification policy (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateacademicregulations/#degreecertificationtextcontainer>). **For engineering students:**

All BS students are expected to complete the BS degree within the standard 8-semester timeline. Units cannot be double counted between BS and MS. Courses taken within the first 8 semesters will first be counted toward completing the BS requirements.

Students who plan to enter an MS program but are unable to complete the BS degree within the 8-semester timeframe can petition to extend their time as an undergraduate. This petition should be addressed to their undergraduate academic advisor and the CIT Undergraduate Dean's Office.

CIT Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

39-109 Grand Challenge Freshman Seminar: Climate Change

Fall and Spring: 9 units

Climate change is considered by many the most serious social, political, and environmental issue of the 21st century. As human activities increase the level of greenhouse gases in the atmosphere, scientists have established the reality of climate change and have estimated its impacts on human society and the natural world. Despite the scientific consensus on its existence, causes, and consequences, a substantial number of Americans and citizens of other countries still question these conclusions and a small but vocal group of doubters continue to challenge the science and scientific consensus on climate change. In spite of some social division over these issues, governments at local, national, and international levels have made concerted efforts to craft policies to address climate change. These policies have shifted over time as the information, attitudes, and technology associated with climate change have evolved. In this course, we will explore the challenges and complexities of climate change by investigating the subject from a variety of angles: scientific, political, rhetorical, cultural, economic, technological, and ethical. Over the course of the semester, well inquire: What is climate change? How do scientists know it is happening? Why is there public debate over it? What solutions are available? And what are the pros and cons of the different solutions?

39-135 DC Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Intermittent: 9 units

This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

39-210 Experiential Learning I

Fall and Spring

The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas.

39-220 Experiential Learning II

Fall and Spring

The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT sophomores, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas. Prerequisite: 39-210

39-245 Rapid Prototype Design

All Semesters: 9 units

This course provides an introduction to rapid design through virtual and physical prototyping. The class covers the engineering design process, problem solving methods, interdisciplinary team work, current industrial practice, and manufacturing process capabilities. The course emphasizes hands on learning. Sophomores have priority while registering for this course. Juniors and seniors will be put on the waitlist, then released once sophomores have registered.

39-250 CIT Undergraduate Projects

Fall

This course number is to be used for Fall CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-251 CIT Undergraduate Projects

Spring

This course number is to be used for Spring CIT freshman research projects only. Student must complete a CIT Undergraduate Project Approval form (located in Scaife Hall 110) and submit for approval. The form must include a complete description and a signature approval from the research advisor/instructor. If the project is approved, the CIT Undergraduate Studies Office will add the course to the student's fall schedule.

39-310 Experiential Learning III

Fall and Spring

The engineer of the 21st century will need to operate effectively in many settings and often with a global perspective. Being curious and constantly looking for inspiration are critical for lifelong learning. This course, designed for all CIT juniors, requires the student to choose and experience activities for development and growth that are not part of formal course work. Acceptable experiences are listed in the course syllabus on Canvas. Prerequisite: 39-220

39-402 Leadership Development Seminar

All Semesters: 9 units

This course is designed for CIT seniors and juniors committed to further developing their leadership skills and potential for sustained impact in the future. The course will be substantive and engaging, while less technically challenging, outright, than thought provoking, edifying, and enjoyable, ideally. The course will build on the foundation of six key leadership pillars, identified by CIT to hone a student's professional and personal development to serve others, and to seek out and nurture opportunities to heighten one's capacity as a person and leader who is: VISIONARY, with clear goals for yourself, your organizations and communities, and others in whose lives you are a part, including the broader society; ETHICAL, with core values and steadfastness in the face of competing objectives, and the resilience to deal with conflicts without moral compromise; ENGAGING, with empathy, attentive interpersonal attributes, outstanding formal and informal communication skills, and the capacity to inspire; TACTICAL, with an ability to operationalize big ideas and bring them to fruition, creating the ideal environment for individual and group success; TECHNICAL, based on your own high-level skill set and the ego strength for inclusion of others with complementary realms of expertise; REFLECTIVE, manifesting in the honest appraisal of personal and organizational success against metrics, and the ability to redirect based on assessment.

39-447 CIT Undergraduate Interdisciplinary Design Project

All Semesters

This course is to be used for undergraduate research projects involving a significant interdisciplinary design component. It can be added by permission only through collaboration with the student, project advisor, and the CIT Dean's Office. For projects that are not interdisciplinary in nature, students should refer to the research number specific to the department in which the research is being completed.

39-500 CIT Honors Research Project

All Semesters

Juniors who have an accumulated QPA of at least 3.5 receive an invitation to participate in the program. This course, open by invitation only, will provide the opportunity for close interaction with a faculty member through independent honors research in a number of disciplinary and interdisciplinary areas, as part of the CIT Honors Research Program. Students will work on their projects during their senior year, earning the equivalent of 18-24 units. Students are required to register for CIT Honor Research Project 39-500. To receive CIT College Honors, a student must complete at least 18 units in 39-500 on the same research topic and submit a 1-page executive summary of your research. Lastly, students must present their research findings at the Undergraduate Research Symposium, "Meeting of the Minds" in May. Although "Meeting of the Minds" is open to any undergraduate research initiatives occurring on campus, it is a requirement for College of Engineering Honors Research students.

Course Website: <https://tinyurl.com/cithonorsresearch> (<https://tinyurl.com/cithonorsresearch/>)

39-601 Special Topics: Additive Manufacturing Processing and Product Development

Fall: 12 units

Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

39-602 Additive Manufacturing and Materials

Fall and Spring: 12 units

This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

39-603 Additive Manufacturing Laboratory

Spring: 12 units

Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Student will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.

Prerequisites: 39-602 or 27-503 or 27-765 or 39-601 or 24-632

39-605 Engineering Design Projects

Fall: 12 units

In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-606 Engineering Design Projects

Spring: 12 units

In this project course, students work in multidisciplinary teams to design products or processes. The course is open to juniors, seniors and graduate students from all parts of the campus community. Each project is sponsored by an industry, government or non-profit partner, and is of real commercial interest to that partner. Students work directly with their partner throughout the semester to establish goals and requirements, evaluate their design as it progresses, and produce a final report, presentation, and, if appropriate, a prototype. Design reviews, held twice during the semester, give students a chance to present their preliminary designs and receive feedback and advice. In completing their designs, teams must consider not only the functionality of their designs, but also the look, feel, appearance, and societal impact. Skills built in this course will include: developing the product statement, establishing goals and constraints for the product, project management, and generating and evaluating design alternatives. As some projects may span multiple semesters with new groups of students, careful documentation of project work is emphasized. Students may take this course for either one or two semesters.

39-647 Special Topics in Design

All Semesters

This course is to be used for Interdisciplinary Engineering Design Independent Study. It can be added by permission only through collaboration with the student, Independent Study project advisor, and the CIT Dean's Office.

39-648 Rapid Prototyping of Computer Systems

Spring: 12 units

This course deals with rapid prototyping, manufacture, and applications of a new generation of wearable computers, with head-mounted display. The design of wearable computers is a multidisciplinary process including: Electronic design, mechanical design, software development, and human-computer interaction. Two classes of wearable computers will be further developed: embedded, custom designed VuMan series, and general purpose Navigator series. Electronic design includes the custom designed computer board, electronic interfacing, and power supply. Industrial designers and mechanical engineers team to design and manufacture with in-house facilities a variety of conformable/lightweight housings. A software development environment and user interface builders support software and application development. Current applications include: Global Position Sensing, Hypertext documents, speech recognition, wireless communications, and digital imaging.

Department of Biomedical Engineering

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Biomedical Engineering Overview

Biomedical engineering education at Carnegie Mellon University reflects the belief that a top biomedical engineer must be deeply trained in both a traditional engineering practice and biomedical sciences. The unique additional major program leverages extensive collaborations with sister departments in the College of Engineering and with major medical institutions in Pittsburgh. This collaborative approach, combined with a rigorous engineering education, confers unique depth and breadth to the education of Biomedical Engineering graduates.

Students who elect Biomedical Engineering as a major must also declare a major in one of the traditional engineering disciplines: Chemical Engineering, Civil Engineering, Electrical & Computer Engineering, Environmental Engineering, Materials Science & Engineering, or Mechanical Engineering.

The curriculum, demanding but readily feasible to complete in four years, is highly rewarding to motivated students.

Common Requirements for the Additional Major

The Biomedical Engineering additional major program takes advantage of curricular overlaps between Biomedical Engineering and traditional engineering majors, such that the additional major can be completed in four years with only a modest increase in course requirements. The requirements for Biomedical Engineering consist of the core, the tracks, and the capstone design course. The core exposes students to basic facets of biomedical engineering to lay a foundation. The tracks allow students to build depth in a specific aspect of biomedical engineering. The capstone design (https://www.cmu.edu/bme/Academics/undergraduate-programs/Resources/undergrad_design.html) project engages students in teamwork to develop real-world applications.

The additional major in Biomedical Engineering should be declared at the same time when declaring a traditional engineering major.

Course Requirements for the Additional Major

Minimum units required for additional major: 93-102

Students majoring in Biomedical Engineering must meet **three** sets of requirements:

1. Biomedical Engineering (BME)
2. A traditional engineering discipline, and
3. College of Engineering General Education (<https://engineering.cmu.edu/education/undergraduate-programs/curriculum/general-education/>) sequence.

The Quality Point Average (QPA) for courses that count toward the additional major must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the additional major.

The course requirements for the BME portion of the additional major are as follows:

Core Courses

(all required)

| | | Units |
|-----------|---|-----------|
| 03-121 | Modern Biology- Fall and Spring | 9 |
| or 03-151 | Honors Modern Biology | |
| 42-101 | Introduction to Biomedical Engineering- Fall and Spring | 12 |
| 42-201 | Professional Issues in Biomedical Engineering- Fall and Spring | 3 |
| 42-202 | Physiology- Fall and Spring | 9 |
| 42-203 | Biomedical Engineering Laboratory- Fall and Spring [#] | 9 |
| 42-302 | Biomedical Engineering Systems Modeling and Analysis- Fall and Spring | 9 |
| 42-401 | Foundation of BME Design- Fall* | 6 |
| 42-402 | BME Design Project- Spring | 9 |
| | | 66 |

[#] Also known as 03-206 for Health Professions Program (<http://www.cmu.edu/hpp/>) students.

* 42-401 serves as the precursor/pre-requisite for 42-402 BME Design Project.

Tracks (Completion of one track is required)

- Biomaterials and Tissue Engineering (BMTE (p. 77))
- Biomechanics (BMEC (p. 78))
- Biomedical Devices (BMDV (p. 78))
- Biomedical Signal and Image Processing (BSIP (p. 79))
- Cellular and Molecular Biotechnology (CMBT (p. 79))
- Neuroengineering (Neuro (p. 80))
- Self-Designed Biomedical Engineering (SBME (p. 80))

Biomaterials and Tissue Engineering (BMTE) Track

Overview

The BMTE track addresses issues at the interface of materials science, biology and engineering. The topics include the interactions between materials and cells or tissues, the effects of such interactions on cells and tissues, the design of materials for biological applications, and the engineering of new tissues.

Targets

The BMTE track is ideal for students interested in combining the education of Biomedical Engineering with Materials Science & Engineering or with Chemical Engineering. Both provide the necessary foundation in chemistry and/or materials science. Students of this track may develop careers in biotechnology, tissue engineering, biopharmaceuticals, and medical devices that leverage materials properties.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMTE Track must take the following combination of **three** courses:

- One (1) **Required** BMTE elective
- Two (2) BMTE Electives (either **Required** or **Additional**)

BMTE Electives

Required BMTE Electives (must take one of the following)

| | | |
|---------------|--|----|
| 42-611 | Biomaterials | 12 |
| 42-612/27-520 | Tissue Engineering | 12 |
| 42-615 | Biomaterial Host Interactions in Regenerative Medicine | 12 |
| 42-667 | Biofabrication and Bioprinting | 12 |

Additional BMTE Electives

| | | |
|--------|--|------|
| 42-613 | Polymeric Biomaterials | 12 |
| 42-616 | Bio-nanotechnology: Principles and Applications | 9 |
| 42-620 | Engineering Molecular Cell Biology | 12 |
| 42-624 | Biological Transport and Drug Delivery | 9 |
| 03-320 | Cell Biology | 9 |
| 42-x00 | BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) | 9-12 |

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Biomechanics (BMEC) Track**Overview**

The BMEC track addresses the application of solid or fluid mechanics to biological and medical systems. It provides quantitative understanding of the mechanical behavior of molecules, cells, tissues, organs, and whole organisms. The field has seen a wide range of applications from the optimization of tissue regeneration to the design of surgical and rehabilitation devices.

Targets

The BMEC track is ideally suited to the combined education of Biomedical Engineering and Mechanical Engineering or Civil & Environmental Engineering. Both provide the necessary foundation in the underlying physical principles and their non-Biomedical Engineering applications. This track may also appeal to students of Electrical & Computer Engineering who are interested in biomedical robotics. Education in biomechanics enables students to pursue careers in medical devices or rehabilitation engineering.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** BMEC Elective
- Two (2) BMEC Electives (either **Required** or **Additional**)

BMEC Electives

Required BMEC Electives (must take at least one of the following)

| | | |
|---------------|--------------------------------|----|
| 42-649 | Introduction to Biomechanics | 12 |
| 42-648 | Cardiovascular Mechanics | 12 |
| 42-645/24-655 | Cellular Biomechanics | 9 |
| 42-691 | Biomechanics of Human Movement | 12 |

Additional BMEC Electives

| | | |
|---------------|---|----|
| 42-641 | Rehabilitation Engineering | 9 |
| 42-640/24-658 | Image-Based Computational Modeling and Analysis | 12 |

| | | |
|--------|--|------|
| 42-444 | Medical Devices | 9 |
| 16-868 | Biomechanics & Motor Control | 12 |
| 16-879 | Medical Robotics | 12 |
| 42-x00 | BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) | 9-12 |

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Biomedical Devices (BMDV) Track**OVERVIEW**

The BMDV track addresses issues at the interface of medicine and engineering. The topics include biomedical sensors, actuators, diagnostic devices, therapeutic devices, instruments, systems, and fundamental topics of device material, device fabrication, and device interaction with biological cells, tissues and organs. The Biomedical Device track will prepare students for leaders in the biomedical device industry and for further education in graduate/medical schools.

TARGETS

The BMDV track will prepare students to be leaders in the biomedical device industry and for further education in graduate/medical schools. It is ideal for students interested in combining the education of Biomedical Engineering with Electrical and Computer Engineering, or with Mechanical Engineering, or with Materials Science & Engineering.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BMDV Track must take must take the following combination of **three** courses:

- One (1) **Required** BMDV Elective
- Two (2) BMDV Electives (either **Required** or **Additional**)

BMDV ELECTIVES

Required BMDV Electives (must take at least one of the following)

| | | |
|--------|--|----|
| 42-660 | Bioinstrumentation | 12 |
| 42-678 | Medical Device Innovation and Realization | 12 |
| 42-693 | Special Topics in Integrated Systems Technology: Micro/Nano Biomedical Devices | 12 |
| 42-694 | Engineering Principles of Medical Devices | 9 |

Additional BMDV Electives

| | | |
|---------------|--|----|
| 42-444 | Medical Devices | 9 |
| 42-611 | Biomaterials | 12 |
| 42-616 | Bio-nanotechnology: Principles and Applications | 9 |
| 42-630 | Introduction to Neural Engineering | 12 |
| 42-641 | Rehabilitation Engineering | 9 |
| 42-648 | Cardiovascular Mechanics | 12 |
| 42-650 | Introduction to Biomedical Imaging | 9 |
| 42-652/18-416 | Nano-Bio-Photonics | 12 |
| 42-675 | Fundamentals of Computational Biomedical Engineering | 12 |
| 16-467 | Human Robot Interaction | 12 |
| 16-879 | Medical Robotics | 12 |
| 18-412 | Neural Technology: Sensing and Stimulation | 12 |

| | | |
|--------|--|---|
| 42-6XX | Clinical Course (Surgery for Engineers/ Precision Medicine/ICU Medicine) | 9 |
| 42-X00 | BME Research* or 39-500 CIT Honors Thesis | 9 |

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Biomedical Signal and Image Processing (BSIP) Track

OVERVIEW

The BSIP track addresses biomedical phenomena based on the information embedded in sensor-detected signals, including digital images and nerve electrical pulses. Students in this track will gain an understanding of the technologies involved in acquiring signals and images, the mathematical principles underlying the processing and analysis of signals, and the applications of signal/image processing methods in basic research and medicine.

TARGETS

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in medical imaging or smart prosthetics. It also interfaces with many clinical practices including radiology, neurology/neurosurgery, and pathology.

REQUIREMENTS

In addition to the Biomedical Engineering core courses, students in the BSIP Track must take the following combination of **three** courses:

- One (1) **Required** BSIP elective
- Two (2) BSIP Electives (either **Required** or **Additional**)

BSIP ELECTIVES

Required BSIP Electives (must take at least one of the following)

| | | |
|--------|--|----|
| 42-650 | Introduction to Biomedical Imaging | 9 |
| 42-668 | "Fun"-damentals of MRI and Neuroimaging Analysis | 9 |
| 42-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |

Additional BSIP Electives

| | | |
|---------------|--|------|
| 42-437 | Biomedical Optical Imaging | 9 |
| 42-640/24-658 | Image-Based Computational Modeling and Analysis | 12 |
| 42-656 | Introduction to Machine Learning for Biomedical Engineers | 9 |
| 42-660 | Bioinstrumentation | 12 |
| 42-675 | Fundamentals of Computational Biomedical Engineering | 12 |
| 16-725 | (Bio)Medical Image Analysis | 12 |
| 18-491 | Digital Signal Processing ¹ | 12 |
| 42-x00 | BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) | 9-12 |

¹ Students make take either 18-491 Fundamentals of Signal Processing OR 18-792 Advanced Digital Signal Processing (but not both)

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research

Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Cellular and Molecular Biotechnology (CMBT) Track

Overview

The CMBT track emphasizes fundamentals and applications of biochemistry, biophysics, and cell biology, and processes on the nanometer to micrometer size scale. Students in this track acquire understanding of the molecular and cellular bases of life processes, and build skills in quantitative modeling of live cell-based biotechnologies and in technologies that exploit the unique properties of biomolecules in non-biological settings.

Targets

The CMBT track is ideally suited for the combined education of Biomedical Engineering and Chemical Engineering, which provides a strong core of chemistry and molecular processing principles. The track may also interest students of Mechanical Engineering, Materials Science & Engineering, or Civil & Environmental Engineering who have an interest in molecular aspects of Biomedical Engineering. The CMBT track prepares students for careers in bio/pharmaceutical, medical diagnostics, biosensors, drug delivery, and biological aspects of environmental engineering.

Requirements

In addition to the Biomedical Engineering core courses, students in the CMBT Track must take the following combination of **three** courses:

- One (1) **Required** CMBT Elective
- Two (2) CMBT Electives (either **Required** or **Additional**)

CMBT Electives

Required CMBT Electives (must take at least one of the following)

| | | |
|--------|--|----|
| 42-620 | Engineering Molecular Cell Biology | 12 |
| 42-621 | Principles of Immunoengineering and Development of Immunotherapy Drugs | 9 |
| 42-624 | Biological Transport and Drug Delivery | 9 |

Additional CMBT Electives

| | | |
|---------------|--|------|
| 42-616 | Bio-nanotechnology: Principles and Applications | 9 |
| 42-626 | Drug Delivery Systems | 9 |
| 42-645/24-655 | Cellular Biomechanics | 9 |
| 03-320 | Cell Biology | 9 |
| 06-722 | Bioprocess Design | 12 |
| 42-x00 | BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) | 9-12 |

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Neuroengineering (Neuro) Track

Overview

The Neuroengineering (Neuro) track uses engineering techniques to examine, understand, and apply the properties of complex neural systems. Areas of interest include the research and development of neuroengineering technologies for sensing, interfacing, imaging, and modulating the nervous systems. Examples of applications include brain-computer interfaces for use in paralysis, neural stimulation device design for sensory and motor prostheses and basic science research, and neural recording and imaging devices.

Targets

This track aligns most naturally with a combined education of Biomedical Engineering and Electrical & Computer Engineering, which lays a solid foundation in signal processing principles. This track prepares students for careers in brain-computer interfaces, neural stimulators, and neuroprosthetics.

Requirements

In addition to the Biomedical Engineering core courses, students in the BMEC Track must take must take the following combination of **three** courses:

- One (1) **Required** Neuro Elective
- Two (2) Neuro Electives (either **Required** or **Additional**)

Neuro Electives

Required Neuro Electives (must take at least one of the following)

| | | |
|--------|------------------------------------|----|
| 42-630 | Introduction to Neural Engineering | 12 |
| 42-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |

Additional Neuro Electives

| | | |
|---------------|--|------|
| 42-437 | Biomedical Optical Imaging | 9 |
| 42-641 | Rehabilitation Engineering | 9 |
| 42-650 | Introduction to Biomedical Imaging | 9 |
| 42-652/18-416 | Nano-Bio-Photonics | 12 |
| 42-656 | Introduction to Machine Learning for Biomedical Engineers | 9 |
| 42-660 | Bioinstrumentation | 12 |
| 42-783 | Neural Engineering Laboratory | 12 |
| 15-386 | Neural Computation | 9 |
| 18-370 | Fundamentals of Control | 12 |
| 18-412 | Neural Technology: Sensing and Stimulation | 12 |
| 18-460 | Optimization | 12 |
| 42-x00 | BME Research* or 39-500 CIT Honors Research Project* or 42-6XX Clinical Course (Surgery for Engineers/Precision Medicine/ICU Medicine) | 9-12 |

* The 42-x00 research project (42-200/300/400 Sophomore/Junior/Senior Biomedical Engineering Research Project OR 39-500 CIT Honors Research Project) must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Some Special Topics and newly offered or intermittently offered courses may be acceptable as track electives. Students should consult with their BME advisors and petition the BME Undergraduate Affairs Committee for permission to include such courses as track electives. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Sample schedules can be found on the BME Additional Major (<https://www.cmu.edu/bme/Academics/undergraduate-programs/major.html>) page on the BME website.

Self-Designed Biomedical Engineering (SBME) Track

The SBME track is aimed at helping highly motivated students who have a strong sense of career direction that falls beyond the scope of regular Biomedical Engineering tracks. Students are allowed to design the "track" portion of the curriculum in consultation with the faculty. Example themes

include medical robotics, embedded medical systems, or computational biomedical engineering.

Requirements

In addition to the Biomedical Engineering core requirements, students must take **three** elective courses of at least 9 units each. These elective courses must form a coherent theme that is relevant to biomedical engineering. In addition, at least one of the elective courses must be judged by the Biomedical Engineering Undergraduate Affairs Committee to have substantial biological or medical content.

If undergraduate research is part of the SBME track, the research project must be on a BME topic that is aligned to the track, supervised or co-supervised by a BME faculty member, and conducted for 9 or more units of credit.

Petition Procedure

1. Students wishing to pursue a self-designed track should first consult with Kristin Kropf (<https://engineering.cmu.edu/directory/bios/kropf-kristin.html>) (Undergraduate Program and Alumni Relations Coordinator).
2. A SBME track proposal must be submitted electronically to Kristin Kropf (<https://engineering.cmu.edu/directory/bios/kropf-kristin.html>) at least three weeks prior to Pre-Registration during the spring of the sophomore year. The proposal must include:
 - The three courses of the designed track, including catalog descriptions and when these courses are expected to be taken.
 - A justification of how these courses form a coherent theme relevant to biomedical engineering and why the regular tracks do not relate to the proposed theme
 - Two alternative courses that may substitute for one of the proposed courses, in case the original course is not available.
3. Once approved by the Biomedical Engineering Undergraduate Affairs Committee, the student must sign an agreement listing the theme and the three courses comprising the SBME track.
4. In the event that issues beyond the student's control, such as course scheduling or cancellation, prevent the student from completing the approved course plan, the student may petition the Biomedical Engineering Undergraduate Affairs Committee to
 - Substitute a course with another course that fits the approved theme, OR
 - Complete one of the regular tracks (all classes)

Minor in Biomedical Engineering

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
 Email: kgaluska@andrew.cmu.edu
<https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html>

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

Minimum units required for minor: 57

| | | |
|-----------|--|------|
| 03-121 | Modern Biology | 9 |
| or 03-151 | Honors Modern Biology | |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 42-202 | Physiology | 9 |
| 42-xxx | BME Elective I | 9-12 |
| 42-xxx | BME Elective II | 9-12 |
| 42-xxx | BME Elective III | 9-12 |

A BME Elective is defined as one of the following:

1. One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.
2. 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.
3. Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Note that non-BME, track elective courses for BME major do not automatically qualify as BME minor electives. Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological/medical *and* engineering contents towards the minor requirements. The course petition form can be found here (<https://www.cmu.edu/bme/Academics/undergraduate-programs/advising.html#ug-course-petition>).

Full-Time Faculty

ABBOTT, ROSALYN, Assistant Professor of Biomedical Engineering - Ph.D., University of Vermont, 2011;

BARATI FARIMANI, AMIR, Assistant Professor, Mechanical Engineering and Biomedical Engineering - Ph.D., University of Illinois at Urbana-Champaign, 2015;

BARTH, ALISON L., Professor, Biological Sciences, and Biomedical Engineering - Ph.D., University of California, Berkeley, 1997;

BETTINGER, CHRISTOPHER J., Professor of Biomedical Engineering and Materials Science & Engineering - Ph.D., Massachusetts Institute of Technology, 2008;

CAMPBELL, PHIL G., Research Professor, Biomedical Engineering, Engineering Research Accelerator, Biological Sciences, and Materials Science & Engineering - Ph.D., The Pennsylvania State University, 1985;

CHALACHEVA, P. SANG, Assistant Teaching Professor of Biomedical Engineering - Ph.D., University of Southern California, 2014;

CHAMANZAR, MAYSAM, Dr. William D. and Nancy W. Strecker Career Development Associate Professor, Electrical and Computer Engineering, Biomedical Engineering - Ph.D., Georgia Institute of Technology, 2012;

CHASE, STEVEN M., Professor of Biomedical Engineering and Center for the Neural Basis of Cognition - Ph.D., Johns Hopkins University, 2006;

CHOSET, HOWIE, Professor, Robotics Institute, Biomedical Engineering, and Electrical & Computer Engineering - Ph.D., California Institute of Technology, 1996;

COHEN-KARNI, TZAHI (ITZHAQ), Professor of Biomedical Engineering and Materials Science & Engineering - Ph.D., Harvard University, 2011;

COOK, KEITH, David Edward Schramm Professor and Head - Ph.D., Northwestern University, 2000;

DANDIN, MARC, Assistant Professor, Electrical & Computer Engineering and Biomedical Engineering - Ph.D., University of Maryland, 2012;

DOMACH, MICHAEL M., Professor, Chemical Engineering and Biomedical Engineering - Ph.D., Cornell University, 1983;

ERICKSON, ZACKORY, Assistant Professor, Robotics Institute and Biomedical Engineering - Ph.D., Georgia Institute of Technology, 2021;

FEDDER, GARY K., Howard M. Wilkoff Professor, Institute for Complex Engineering Systems, Biomedical Engineering, Electrical & Computer Engineering, Robotics Institute - Ph.D., University of California, Berkeley, 1994;

FEINBERG, ADAM W., Arthur Hamerschlag Career Development Professor; Professor of Biomedical Engineering and Materials Science & Engineering - Ph.D., University of Florida, 2004;

GALEOTTI, JOHN, Senior Systems Scientist, Robotics Institute and Associate Professor of Biomedical Engineering - Ph.D., Carnegie Mellon University, 2007;

GEYER, HARMUT, Associate Professor, Robotics Institute and Biomedical Engineering - Ph.D., Friedrich-Schiller-University of Jena, Germany, 2005 ;

GITTIS, ARYN, Associate Professor, Biological Sciences, and Biomedical Engineering - Ph.D., University of California, San Diego, 2008;

GROVER, PULKIT, Angel Jordan Associate Professor, Electrical & Computer Engineering, Center for Neural Basis of Cognition, and Biomedical Engineering - Ph.D., University of California, Berkeley, 2010;

GUTIÉRREZ, NOELIA GRANDE, Assistant Professor, Mechanical and Biomedical Engineering - PhD, Stanford, 2019;

HALILAJ, ENI, Assistant Professor, Mechanical Engineering and Biomedical Engineering - Ph.D., Brown University, 2015;

JAMMAL, ZAKIA, Systems Faculty, Robotics Institute; Assistant Research Professor, Biomedical Engineering - Ph.D.,

HE, BIN, Trustee Professor of Biomedical Engineering, Electrical & Computer Engineering, Neuroscience Institute - Ph.D., Tokyo Institute of Technology, 1988;

JUST, MARCEL, D.O. Hebb University Professor of Psychology and Biomedical Engineering Director, Center for Cognitive Brain Imaging - Ph.D., Stanford University, 1972;

KAINERSTORFER, JANA M., Associate Professor of Biomedical Engineering - Ph.D., University of Vienna, 2010;

KASS, ROBERT, Maurice Falk Professor, Statistics, Department of Machine Learning, Center for the Neural Basis of Cognition, and Biomedical Engineering Interim co-Director, Center for the Neural Basis of Cognition - Ph.D., University of Chicago, 1980;

KELLY, SHAWN, Adjunct Associate Professor of Biomedical Engineering - Ph.D., Massachusetts Institute of Technology, 2003;

KUHLMAN, SANDRA, Associate Professor, Biological Sciences, and Biomedical Engineering - Ph.D., University of Kentucky, 2001;

LEDUC, PHILIP R., William J. Brown Professor of Mechanical Engineering, Biomedical Engineering, and Biological Sciences - Ph.D., Johns Hopkins University, 1999;

LEE, TAI SING, Professor, Computer Science, Center for the Neural Basis of Cognition and Biomedical Engineering - Ph.D., Harvard University, 1993;

MAJIDI, CARMEL, Associate Professor of Mechanical Engineering and Biomedical Engineering - Ph.D., University of California, Berkeley; Carnegie Mellon, 2007-

MOORE, AXEL, Assistant Professor, Biomedical Engineering - Ph.D., University of Delaware, 2017;

MOURA, JOSE M. F., University Professor of Electrical & Computer Engineering and Biomedical Engineering - Ph.D., Massachusetts Institute of Technology, 1975;

OLSON, CARL, Professor, Center for the Neural Basis of Cognition and Biomedical Engineering - Ph.D., University of California, Berkeley, 1979;

OZDOGANLAR, BURAK, Ver Planck Professor, Mechanical Engineering and Biomedical Engineering - Ph.D., University of Michigan, 1999;

PALCHESKO, RACHELLE, Assistant Teaching Professor of Biomedical Engineering - Ph.D., Duquesne University, 2011;

PANAT, RAHUL, Russell V. Trader Associate Professor, Mechanical Engineering, Civil & Environmental Engineering, Materials Science & Engineering, and Biomedical Engineering - Ph.D., University of Illinois at Urbana-Champaign, 2004;

REN, XI (CHARLIE), Associate Professor of Biomedical Engineering - Ph.D., Peking University, 2011;

RIVIERE, CAMERON N., Associate Research Professor, Robotics Institute and Biomedical Engineering - Ph.D., Johns Hopkins University, 1995;

SCHNEIDER, JAMES W., Professor of Chemical Engineering and Biomedical Engineering - Ph.D., University of Minnesota, 1998;

SHIMADA, KENJI, Theodore Ahrens Professor, Mechanical Engineering and Biomedical Engineering - Ph.D., Massachusetts Institute of Technology, 1993;

SHINN-CUNNINGHAM, BARBARA, Director, Carnegie Mellon Neuroscience Institute Professor, Center for the Neural Basis of Cognition, Biomedical Engineering, Psychology, and Electrical & Computer Engineering - Ph.D., Massachusetts Institute of Technology, 1994;

SMITH, MATTHEW, Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., New York University, 2003;

SYDLIK, STEFANIE, Professor of Chemistry and Biomedical Engineering – Ph.D., Massachusetts Institute of Technology, 2012;

TAYLOR, REBECCA, Ph.D. – Associate Professor of Mechanical Engineering and Biomedical Engineering, Stanford University, 2013;

TILTON, ROBERT D. , Chevron Professor; Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Stanford University, 1991;

TRUMBLE, DENNIS, Emeritus Research Professor, Biomedical Engineering and Center for the Neural Basis of Cognition – Ph.D., Carnegie Mellon University, 2010;

TUCKER, CONRAD, Arthur Hamerschlag Career Development Professor of Mechanical Engineering, Biomedical Engineering, Machine Learning, and the Robotics Institute – PhD, MBA, University of Illinois, Urbana-Champaign, 2011;

VERSTYNEN, TIMOTHY, Associate Professor, Psychology, Center for the Neural Basis of Cognition and Biomedical Engineering – Ph.D., University of California, Berkeley, 2006;

WANG, YU-LI, Mehrabian Professor of Biomedical Engineering – Ph.D., Harvard University, 1980;

WASHBURN, NEWELL R. , Associate Professor of Biomedical Engineering, Chemistry, and Materials Science & Engineering – Ph.D., University of California, Berkeley, 1998;

WAYNE, ELIZABETH, Assistant Professor, Biomedical Engineering and Chemical Engineering – Ph.D., Cornell University, 2015;

WEBER, DOUGLAS J, Akhtar and Bhutta Professor, Mechanical Engineering, Neuroscience Institute and Biomedical Engineering – Ph.D., Arizona State University, 2001;

WEBSTER-WOOD, VICTORIA , Assistant Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., Case Western Reserve University, 2017;

WHITEHEAD, KATHRYN A, Professor of Chemical and Biomedical Engineering – Ph.D., University of California, Santa Barbara, 2007;

WOOD, SOSSENA, Assistant Professor of Biomedical Engineering – Ph.D., University of Pittsburgh, 2018;

YTTRI, ERIC, Assistant Professor, Biological Sciences, Center for the Neural Basis of Cognition, Biomedical Engineering – Ph.D., Washington University in St Louis, 2011;

YU, BYRON, Gerard G. Elia Career Development Professor of Biomedical Engineering and Electrical & Computer Engineering – Ph.D., Stanford University, 2007;

YU, KAI, Research Scientist of Biomedical Engineering – Ph.D., University of Minnesota, Minneapolis, 2018;

ZAPANTA, CONRAD M., Associate Dean of Undergraduate Studies, College of Engineering and Teaching Professor, Biomedical Engineering, – Ph.D., The Pennsylvania State University, 1997;

ZHANG, YONGJIE JESSICA, George Tallman Ladd and Florence Barrett Ladd Professor, Mechanical Engineering and Biomedical Engineering – Ph.D., University of Texas at Austin, 2005;

ZHENG, SIYANG, Professor, Biomedical Engineering and Electrical and Computer Engineering – Ph.D., California Institute of Technology, 2007;

Department of Biomedical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

42-101 Introduction to Biomedical Engineering

Fall and Spring: 12 units

This course will provide exposure to basic biology and engineering problems associated with living systems and health care delivery. Examples will be used to illustrate how basic concepts and tools of science and engineering can be brought to bear in understanding, mimicking and utilizing biological processes. The course will focus on four areas: biotechnology, biomechanics, biomaterials and tissue engineering and biosignal and image processing and will introduce the basic life sciences and engineering concepts associated with these topics.

42-200 Sophomore BME Research Project

Fall and Spring

Research projects for sophomores under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-201 Professional Issues in Biomedical Engineering

Fall and Spring: 3 units

This course exposes students to many of the issues that biomedical engineers face. It provides an overview of professional topics including bioethics, regulatory issues, communication skills, teamwork, and other contemporary issues. Outside speakers and case studies will describe real world problems and professional issues in biotechnology and bioengineering, and progress toward their solution.

42-202 Physiology

Fall and Spring: 9 units

This course is an introduction to human physiology and includes units on all major organ systems. Particular emphasis is given to the musculoskeletal, cardiovascular, respiratory, digestive, excretory, and endocrine systems. Modules on molecular physiology tissue engineering and physiological modeling are also included. Due to the close interrelationship between structure and function in biological systems, each functional topic will be introduced through a brief exploration of anatomical structure. Basic physical laws and principles will be explored as they relate to physiologic function. Prerequisite or co-requisite: 03-121 Modern Biology, or permission of instructor.

Prerequisites: 03-151 or 03-121

42-203 Biomedical Engineering Laboratory

Fall and Spring: 9 units

This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Pre-med students should register for 03-206. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Prerequisites: 42-101 and (03-121 or 03-151)

42-300 Junior BME Research Project

Fall and Spring

Research projects for juniors under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-302 Biomedical Engineering Systems Modeling and Analysis

Fall and Spring: 9 units

This course will prepare students to develop mathematical models for biological systems and for biomedical engineering systems, devices, components, and processes and to use models for data reduction and for system performance analysis, prediction and optimization. Models considered will be drawn from a broad range of applications and will be based on algebraic equations, ordinary differential equations and partial differential equations. The tools of advanced engineering mathematics comprising analytical, computational and statistical approaches will be introduced and used for model manipulation.

Prerequisites: 21-260 or 06-262 or 18-202

42-400 Senior BME Research Project

Fall and Spring

Research projects for seniors under the direction of a regular or adjunct BME faculty member. Arrangements may also be made via the Associate Head of BME for off-campus projects provided that a regular or adjunct BME faculty member agrees to serve as a co-advisor. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the research advisor. The agreement should be summarized in a two-page project description with sign-off by the research advisor and a copy submitted for review and filing with the BME Department. A final written report of the results is required. Units may vary from 9 to 12 according to the expected time commitment, with one unit corresponding to 1 hour of research per week. One (but not more than one) semester of research, if registered for at least 9 units, may be counted as a restricted elective course toward the BME additional major.

42-401 Foundation of BME Design

Fall: 6 units

This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report.

Prerequisite: 42-101

42-402 BME Design Project

Spring: 9 units

This course sequence introduces Biomedical Engineering students to the design of useful biomedical products to meet a specific medical need. Students will learn to identify product needs, how to specify problem definitions and to use project management tools. Methods to develop creativity in design will be introduced. The course sequence is comprised of two parts: 42-401 is offered in the Fall semester and provides the students the opportunity to form project teams, select and define a project, create a development plan, and complete an initial prototype. 42-402 is offered in the Spring semester is a full semester course and completes the plan that was developed in the fall semester. This course culminates in the completion of multiple prototypes, a poster presentation, and a written report.

42-437 Biomedical Optical Imaging

Fall: 9 units

Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. NOTE: 42-437 is intended for undergraduates only. Pre-requisite: 33-107 Physics II for Engineering Students or permission of the instructor. Prerequisite: 33-142

42-444 Medical Devices

Fall: 9 units

This survey course is an introduction to the engineering, clinical, legal, regulatory and business aspects of medical device performance and failure. Topics covered include a broad range of successful medical devices in clinical use, as well as historical case studies of devices that were withdrawn from the market as a consequence of noted failures. In-depth study of specific medical devices will include cardiovascular, orthopedic, and neurological disciplines. We will study best practices employed in the clinical setting, principles governing the design processes, and modes of failure as a risk to the patient population. Additional lectures will provide fundamental topics concerning biomaterials used for implantable medical devices (metals, polymers, ceramics), biocompatibility, imaging, patient risks and mechanisms of failure (wear, corrosion, fatigue, fretting, etc.). The level of technical content will require junior standing for MCS and CIT students, a degree in science or engineering for non-MCS or non-CIT graduate students, or permission of the instructor for all other students.

42-447 Rehabilitation Engineering

Fall: 9 units

Rehabilitation engineering is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. This course surveys assistive technologies designed for a variety of functional limitations - including mobility, communication, hearing, vision, and cognition - as they apply to activities associated with employment, independent living, education, and integration into the community. This course considers not only technical issues in device development, but also the psychosocial factors and market forces that influence device acceptance by individuals and the marketplace. Open only to students with junior standing who have had at least one engineering class or by permission of instructor.

42-610 Introduction to Biomaterials

Spring: 9 units

Understanding the fundamentals of biomaterials structure-function relationships pertaining to material functions and to cell and tissue environments will be a prime goal. The course will be composed of lectures, readings, projects and technical writing assignments. The synthesis, characterization and functional properties of organic and inorganic biomaterials and the processes involved in their use in tissue engineering and regenerative medicine will be discussed. Fundamental issues related to the utility of biomaterials, including biomechanics, transport, degradability, biointerfaces and biocompatibility, stability, fate in the body will be covered, along with some of the basic approaches to characterization. Clinical applications for biomaterials and new directions in design and synthesis to achieve better biocompatibility will be emphasized.

42-611 Biomaterials

Spring: 12 units

This class serves as an overview of the landscape of biomaterial engineering and research. This course will cover the application of materials in biological environments, focusing on structure-processing-property relationships, engineering design principles, and how the biological environment affects the material properties. This course will focus on applications of a variety of materials that interface with biological systems including natural biopolymers, synthetic polymers, metals, and ceramics. Topics include considerations in molecular design of biomaterials, fundamentals of thermodynamic and kinetics relationships, the application of bulk and surface properties in the design of medical devices, and understanding tissue-biomaterials interactions. This course will discuss practical applications of materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies. Students will be assessed with homework assignments and quizzes. At the end of the class, in teams, students will apply the concepts they have learned to write and present a focused review on a biomaterial design/concept that excites them.

42-612 Tissue Engineering

Spring: 12 units

This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

42-613 Polymeric Biomaterials

Spring: 12 units

This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed.

42-614 Stem Cell Engineering

Intermittent: 9 units

This course will give an overview over milestones of stem cell research and will expose students to current topics at the frontier of this field. It will introduce students to the different types of stem cells as well as environmental factors and signals that are implicated in regulating stem cell fate. The course will highlight techniques for engineering of stem cells and their micro-environment. It will evaluate the use of stem cells for tissue engineering and therapies. Emphasis will be placed on discussions of current research areas and papers in this rapidly evolving field. Students will pick a class-related topic of interest, perform a thorough literature search, and present their findings as a written report as well as a paper review and a lecture. Lectures and discussions will be complemented by practical lab sessions, including: stem cell harvesting and culture, neural stem cell transfection, differentiation assays, and immunostaining, polymeric microcapsules as advanced culture systems, and stem cell integration in mouse brain tissue. The class is designed for graduate students and upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

42-615 Biomaterial Host Interactions in Regenerative Medicine

Intermittent: 12 units

This course will provide students with hands-on experience in investigating host responses to synthetic and naturally biomaterials used in regenerative medicine applications. Students will gain experience in the analysis of host responses to these biomaterials as well as strategies to control host interaction. Biomaterial biocompatibility, immune interactions, tissue healing and regeneration will be addressed. Students will integrate classroom lectures with laboratory skills evaluating host-material interactions in a laboratory setting. Laboratory characterization techniques will include cell culture techniques, microscopic, cytochemical, immunocytochemical and histological analyses. Prior knowledge in physiology is helpful.

42-616 Bio-nanotechnology: Principles and Applications

Fall: 9 units

Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy. This class is open for both undergraduate (junior/senior) and graduate students.

42-620 Engineering Molecular Cell Biology

Fall: 12 units

Cells are not only basic units of living organisms but also fascinating engineering systems that exhibit amazing functionality, adaptability, and complexity. Applying engineering perspectives and approaches to study molecular mechanisms of cellular processes plays a critical role in the development of contemporary biology. At the same time, understanding the principles that govern biological systems provides critical insights into the development of engineering systems. The goal of this course is to provide basic molecular cell biology for engineering students with little or no background in cell biology, with particular emphasis on integrating engineering concepts throughout the entire learning process of modern molecular and cellular biology. This course will prepare advanced undergraduate or graduate students with the essential knowledge and mindset for future research endeavors involving engineering biological systems at molecular and cellular levels. This course, besides introducing the fundamental biological knowledge, aims to enhance students' comprehension and appreciation of (1) how engineering approaches have led to our current understanding of molecular and cell biology; (2) what the available engineering approaches are that allow manipulation and even creation of biological systems at molecular, cellular and tissue levels; (3) what the current challenges are in molecular and cell biology that could be solved one day by engineering innovation. Course topics include the engineering of cellular components (DNA, RNA, protein, cell membrane, mitochondria, extracellular matrix) and cellular processes (metabolism, proliferation, cell death, tissue formation). Pre-requisites: None. Prior completion of 03-121 Modern Biology is suggested but not required.

42-621 Principles of Immunoengineering and Development of Immunotherapy Drugs

Fall: 9 units

This course will provide context for the application of engineering principles to modulate the immune system to approaches problems in human health. Basic understanding of the components and function of the innate and adaptive immune system. Students will leave with a basic understanding of immunology and of the engineering techniques used to develop and characterize immunotherapy systems. Where appropriate, we will discuss how immunoengineering fits into other disciplines of engineering such as mechanical, chemical, and materials science. Because the purpose of immunoengineering is disease treatment, we will discuss, the therapy pipeline, development of clinical trials and the FDA approval process. Immunotherapy will also be assessed within different disease contexts including cancer, infectious disease, allergies, prosthetics and implants, neuro and musculoskeletal disorders.

42-622 Bioprocess Design

Spring: 9 units

This course is designed to link concepts of cell culture, bioseparations, formulation and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. The format of the course is a mixture of equal parts lecture, open discussion, and participant presentation. Course work consists of team-oriented problem sets of an open-ended nature and individual-oriented industry case studies. The goals of the course work are to build an integrated technical knowledge base of the manufacture of biologically based pharmaceuticals and U.S. biotechnology industry. Working knowledge of cell culture and modern biology, biochemistry and differential equations is assumed. Pre-requisite: 42-321 Cellular and Molecular Biotechnology or both 03-232 Biochemistry and 06-422 Chemical Reaction Engineering, or instructor permission.

Prerequisites: 06-422 or 42-321 or 03-232

42-623 Cellular and Molecular Biotechnology

Fall: 9 units

This course will provide students with an introduction to biotechnology in an engineering context. The focus will be on using microorganisms to prepare therapeutically and technologically relevant biochemicals. Topics to be covered include cellular and microbial metabolism, recombinant DNA methodologies, bioreactor design, protein separation and purification, and systems approaches to biotechnology. Prerequisites: (42-202 Physiology OR 03-121 Modern Biology OR 03-232 Biochemistry) AND (06-262 Mathematical Methods of Chemical Engineering OR 21-260 Differential Equations) OR permission of instructor.

42-624 Biological Transport and Drug Delivery

Spring: 9 units

Analysis of transport phenomena in life processes on the molecular, cellular, organ and organism levels and their application to the modeling and design of targeted or sustained release drug delivery technologies. Coupling of mass transfer and reaction processes will be a consistent theme as they are applied to rates of receptor-mediated solute uptake in cells, drug transport and biodistribution, and drug release from delivery vehicles. Design concepts underlying advances in nanomedicine will be described.

42-625 Surgery for Engineers

Spring: 9 units

This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. A number of visits to the medical center are anticipated for hands on experience with a number of technologies utilized by surgeons to demonstrate the result of advances in biomedical engineering. These experiences are expected to include microvascular surgery, robotic surgery, laparoscopic, and endoscopic techniques. Tours of the operating room and shock trauma unit will be arranged. If possible observation of an operative procedure will be arranged (if scheduling permits). Invited surgeons will represent disciplines including cardiovascular surgery, plastic and reconstructive surgery, surgical oncology, trauma surgery, minimally invasive surgery, oral and maxillofacial surgery, bariatric surgery, thoracic surgery, orthopedic surgery, and others. The Primary Instructor is Howard Edington, M.D., MBA System Chairman of Surgery, Allegheny Health Network. This course meets once a week for 3 hours. Several sessions will be held at the Medical Center, transport provided. Pre-requisite: Physiology 42-202 and one of the introductory engineering courses, 42-101, 06-100, 12-100, 18-100, 19-101, 24-101, or 27-100 Priority for enrollment is given to BME Graduate students and additional majors, followed by BME minors.

42-626 Drug Delivery Systems

Fall and Spring: 9 units

The body is remarkable in its ability to sequester and clear foreign entities - whether they be "bad" (e.g. pathogens) or "good" (e.g. therapeutic drugs). This course will explore the design principles being used to engineer modern drug delivery systems capable of overcoming the body's innate defenses to achieve therapeutic effect. Specifically, we will study the chemistry, formulation, and mechanisms of systems designed to deliver nucleic acids, chemotherapeutics, and proteins across a variety of physiological barriers. Scientific communication plays a prominent role in the course, and students will have several opportunities to strengthen their communication skills through journal club presentations, proposal writing and constructive feedback. This is a graduate level course that is also open to undergraduate seniors.

42-630 Introduction to Neural Engineering

Spring: 12 units

Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-631 Neural Data Analysis

Fall: 12 units

The vast majority of behaviorally relevant information is transmitted through the brain by neurons as trains of action potentials. How can we understand the information being transmitted? This class will cover the basic engineering and statistical tools in common use for analyzing neural spike train data, with an emphasis on hands-on application. Topics may include neural spike train statistics (Poisson processes, interspike intervals, Fano factor analysis), estimation (MLE, MAP), signal detection theory (d-prime, ROC analysis, psychometric curve fitting), information theory, discrete classification, continuous decoding (PVA, OLE), and white-noise analysis. Each topic covered will be linked back to the central ideas from undergraduate probability, and each assignment will involve actual analysis of neural data, either real or simulated, using Matlab. This class is meant for upper-level undergrads or beginning graduate students, and is geared to the engineer who wants to learn the neurophysiologist's toolbox and the neurophysiologist who wants to learn new tools. Those looking for broader neuroscience application (eg, fMRI) or more focus on regression analysis are encouraged to take 36-746. Those looking for more advanced techniques are encouraged to take 18-699. Prerequisites: undergraduate probability (36-225/227, or its equivalent), some familiarity with linear algebra and Matlab programming

42-632 Neural Signal Processing

Spring: 12 units

The brain is among the most complex systems ever studied. Underlying the brain's ability to process sensory information and drive motor actions is a network of roughly 10^{11} neurons, each making 10^3 connections with other neurons. Modern statistical and machine learning tools are needed to interpret the plethora of neural data being collected, both for (1) furthering our understanding of how the brain works, and (2) designing biomedical devices that interface with the brain. This course will cover a range of statistical methods and their application to neural data analysis. The statistical topics include latent variable models, dynamical systems, point processes, dimensionality reduction, Bayesian inference, and spectral analysis. The neuroscience applications include neural decoding, firing rate estimation, neural system characterization, sensorimotor control, spike sorting, and field potential analysis. Prerequisites: 18-290; 36-217, or equivalent introductory probability theory and random variables course; an introductory linear algebra course; senior or graduate standing. No prior knowledge of neuroscience is needed.

42-638 Introduction to Biophotonics

Spring: 9 units

Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. Pre-requisite: College level physics covering electromagnetism and optics or permission of the instructor.

42-639 Introduction to Neural Engineering

Intermittent: 12 units

Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-640 Image-Based Computational Modeling and Analysis

Spring: 12 units

Biomedical modeling and visualization play an important role in mathematical modeling and computer simulation of real/artificial life for improved medical diagnosis and treatment. This course integrates mechanical engineering, biomedical engineering, computer science, and mathematics together. Topics to be studied include medical imaging, image processing, geometric modeling, visualization, computational mechanics, and biomedical applications. The techniques introduced are applied to examples of multi-scale biomodeling and simulations at the molecular, cellular, tissue, and organ level scales.

42-641 Rehabilitation Engineering

Fall: 9 units

Rehabilitation engineering is the systematic application of engineering sciences to design, develop, adapt, test, evaluate, apply, and distribute technological solutions to problems confronted by individuals with disabilities. This course focuses on assistive technologies - technologies designed for use in the everyday lives of people with disabilities to assist in the performance of activities of daily living. The course surveys assistive technologies designed for a variety of functional limitations - including mobility, communication, hearing, vision, and cognition - as they apply to activities associated with employment, independent living, education, and integration into the community. This course considers not only technical issues in device development, but also the psychosocial factors and market forces that influence device acceptance by individuals and the marketplace. The class is designed for graduate students and upper undergraduates.

42-643 Microfluidics

Intermittent: 12 units

This course offers an introduction to the emerging field of microfluidics with an emphasis on chemical and life sciences applications. During this course students will examine the fluid dynamical phenomena underlying key components of "lab on a chip" devices. Students will have the opportunity to learn practical aspects of microfluidic device operation through hands-on laboratory experience, computer simulations of microscale flows, and reviews of recent literature in the field. Throughout the course, students will consider ways of optimizing device performance based on knowledge of the fundamental fluid mechanics. Students will explore selected topics in more detail through a semester project. Major course topics include pressure-driven and electrokinetically-driven flows in microchannels, surface effects, micro-fabrication methods, micro/nanoparticles for biotechnology, biochemical reactions and assays, mixing and separation, two-phase flows, and integration and design of microfluidic chips. Pre-requisites: 24-231 or 06-261 or 12-355 or instructor permission.

42-645 Cellular Biomechanics

Intermittent: 9 units

This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by motor molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec. Prerequisite: Instructor permission. Prerequisites: None. Corequisites: None. Cross Listed Courses: 24-655 Notes: None. Reservations:

42-648 Cardiovascular Mechanics

Spring: 12 units

The primary objective of the course is to learn to model blood flow and mechanical forces in the cardiovascular system. After a brief review of cardiovascular physiology and fluid mechanics, the students will progress from modeling blood flow in a.) small-scale steady flow applications to b.) small-scale pulsatile applications to c.) large-scale or complex pulsatile flow applications. The students will also learn how to calculate mechanical forces on cardiovascular tissue (blood vessels, the heart) and cardiovascular cells (endothelial cells, platelets, red and white blood cells), and the effects of those forces. Lastly, the students will learn various methods for modeling cardiac function. When applicable, students will apply these concepts to the design and function of selected medical devices (heart valves, ventricular assist devices, artificial lungs).

42-649 Introduction to Biomechanics

Fall: 12 units

The purpose of this course is to achieve a broad overview of the application of mechanics to the human body. This includes solid, fluid, and viscoelastic mechanics applied to single cells, the cardiovascular system, lungs, muscles, bones, and human movement. The physiology of each system will be reviewed as background prior to discussing mechanics applications within that system. Prior knowledge/experience in statics, fluid mechanics, and biology are helpful.

42-650 Introduction to Biomedical Imaging

Fall: 9 units

The field of medical imaging describes methods of seeing the interior of the human body, as well as visual representation of tissue and organ function. The materials covered in this course will give an overview of existing medical imaging devices used in a clinical and pre-clinical setting. The course presents the principles of medical imaging technologies, explaining the mathematical and physical principles, as well as describing the fundamental aspects of instrumentation design. Students will gain a thorough understanding of how these methods are used to image morphological and physiological features. Imaging methods will include Ultrasound, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), as well as optical methods. For each method, the fundamental imaging principles will be discussed, and examples of clinical applications will be presented. No prior knowledge of imaging methods is required.

42-652 Nano-Bio-Photonics

Spring: 12 units

Light can penetrate biological tissues non-invasively. Most of the available bio-optic tools are bulky. With the advent of novel nanotechnologies, building on-chip integrated photonic devices for applications such as sensing, imaging, neural stimulation, and monitoring is now a possibility. These devices can be embedded in portable electronic devices such as cell phones for point of care diagnostics. This course is designed to convey the concepts of nano-bio-photonics in a practical way to prepare students to engage in emerging photonic technologies. The course starts with a review of electrodynamic of lightwaves. The appropriate choice of wavelength and material platform is the next topic. Then optical waveguides and resonators are discussed. Resonance-based sensing is introduced followed by a discussion of the Figure of Merits (FOMs) used to design on-chip sensors. Silicon photonics is introduced as an example of a CMOS-compatible platform. On-chip spectroscopy is the next topic. The second part covers nano-plasmonics for bio-detection and therapy. The design methods are discussed, followed by an overview of nanofabrication and chemical synthesis, and then a discussion of applications. The last part of this course will be dedicated to a review of recent applications such as Optogenetic neural stimulation, Calcium imaging, Cancer Imaging and Therapy. Senior or graduate standing required. This course is cross-listed with 18416. Although students in 18-616 and 18-416 will share the same lectures and recitations, students in 18-616 will receive distinct course projects. Students in 18-416 and 18-616 will be graded on separate curves. Prerequisite: 21-260

42-655 Biostatistics

Spring: 9 units

This course introduces statistical methods for making inferences in engineering, biology and medicine. Students will learn how to select the most appropriate methods, how to apply these methods to actual data, and how to read and interpret computer output from a commonly used statistical package. The topics covered are descriptive statistics; elementary probability; discrete and continuous random variables and their distributions; hypothesis testing involving interval (continuous and discrete) and categorical (nominal and ordinal) variables, for two and three or more treatments; simple and multiple linear regression; time-series analysis; clustering and classification; and time-to-event (survival) analysis. Students will also learn how to write the statistical component of a "Results" section for a scientific paper and learn about the limitations of the statistical analyses. Basic familiarity with probability and probability distribution preferred but not required.

42-656 Introduction to Machine Learning for Biomedical Engineers

Fall: 9 units

This course introduces fundamental concepts, methods and applications in machine learning and datamining. We will cover topics such as parametric and non-parametric learning algorithms, support vector machines, neural networks, clustering, clustering and principal components analysis. The emphasis will be on learning high-level concepts behind machine learning algorithms, and applying them to biomedical-related problems. This course is intended for advanced undergraduate and graduate students in Biomedical Engineering or related disciplines. Students should have experience with high-level programming language such as Python/Matlab, basic familiarity with probability, statistics and linear algebra, and should be comfortable with manipulating vectors and matrices.

42-660 Bioinstrumentation

Spring: 12 units

This course aims to build concepts and skills in electronics for the design and construction of instruments for biomedical applications. The course uses a flipped, fast-paced format to cover a range of electronic components and circuits, including resistors, capacitors, transistors, sensors, actuators, amplifiers, signal filters, and microcontrollers, through lectures, tutorials, weekly lab projects, and term projects. Students, with or without a background in electronics, will gain hands-on skills to build functional instruments for physiological measurements such as temperature, gas concentration, blood pressure, and EKG signals. Prerequisites: 42-101 and 42-202

42-661 Surgery for Engineers

Spring: 9 units

This course explores the impact of engineering on surgery. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. A number of visits to the medical center are anticipated for hands on experience with a number of technologies utilized by surgeons to demonstrate the result of advances in biomedical engineering. These experiences are expected to include microvascular surgery, robotic surgery, laparoscopic, and endoscopic techniques. Tours of the operating room and shock trauma unit will be arranged. If possible observation of an operative procedure will be arranged (if scheduling permits). Invited surgeons will represent disciplines including cardiovascular surgery, plastic and reconstructive surgery, surgical oncology, trauma surgery, minimally invasive surgery, oral and maxillofacial surgery, bariatric surgery, thoracic surgery, orthopedic surgery, and others. The Primary Instructor is Howard Edington, M.D., MBA System Chairman of Surgery, Allegheny Health Network. This course meets once a week for 3 hours. Several sessions will be held at the Medical Center, transport provided. Pre-requisite: Physiology 42-202 and one of the introductory engineering courses, 42-101, 06-100, 12-100, 18-100, 19-101, 24-101, or 27-100 Priority for enrollment is given to BME Graduate students and additional majors, followed by BME minors. Prerequisites: 42-202 and (27-100 or 24-101 or 19-101 or 18-100 or 12-100 or 42-101 or 06-100)

42-663 Computational Methods in BME

Spring: 12 units

This goal of this course is to enable students with little or no programming background to solve simple computational problems in science and engineering. Emphasis will be placed on enabling students to use currently available numerical methods (rather than developing anew) to solve engineering problems. Upon completing the course, the successful student will be able to use basic knowledge regarding computer architecture, data types, binary arithmetic, and programming, to solve sample quantitative problems in engineering. Topics will include: solving linear systems of equations, model fitting using least squares techniques (linear and nonlinear), data interpolation, numerical integration and differentiation, solving differential equations, and data visualization. Specific example computations in each topic above will be drawn from problems in physics, chemistry, as well as signal and image processing, and biomedical engineering. Students will work independently in groups for a final project. Matlab will be used as the programming language/environment for this class, although different languages such as C, Java, and Python will be briefly discussed (time permitting). May count as practicum for practicum-option MS. Pre-requisite: Calculus, multivariate calculus, linear algebra, and differential equations

42-665 Brain-Computer Interface: Principles and Applications

Spring: 9 units

This course provides an introduction and comprehensive review of the concepts, principles and methods of Brain-computer interface (BCI) technology. BCIs have emerged as a novel technology that bridges the brain with external devices. BCIs have been developed to decode human intention, leading to direct brain control of a computer or device, bypassing the neuromuscular pathway. Bi-directional brain-computer interfaces not only allows device control, but also opens the door for modulating the central nervous system through neural interfacing. Using various recorded brain signals that reflect the "intention" of the brain, BCI systems have shown the capability to control external devices, such as computers and robots. Neural stimulation using electrical, magnetic, optical and acoustic energy has shown capability to better understanding of the brain functions and intervene with central nervous systems. This course teaches the fundamentals how a BCI system works and various building blocks of BCIs, from signal acquisition, signal processing, feature extraction, feature translation, neurostimulation, to device control, and various applications. Examples of noninvasive BCIs are discussed to provide an in-depth understanding of the noninvasive BCI technology. Open to seniors or graduate students in engineering or science programs, or upon instructor's approval (for exceptional juniors, e.g.).

42-666 Neuroengineering Practicum

Fall: 9 units

This course will examine topics and issues related to ethics, professional conduct, conflicts, plagiarism, copyright, authorship, research design considerations, IRB, IACUC, intellectual properties, review process, regulatory science and FDA process, professional presentations, and technical writing in neuroengineering. Students will discuss neuro-ethical implications of neural technologies and learn about the process of bringing such technologies to market, including intellectual property and FDA approval considerations. Students will discuss essential career development skills for a neuroengineering R and D career in academia and industry. An important component of the course is to develop students' communications skills including developing an effective research proposal, as well as effective oral presentations of the ideas developed in the proposal and technical report. The essentials for successful proposal writing will be discussed in case studies, in the form of fellowship applications. Each student will be required to develop a research proposal based upon students' own research or an emerging research topic in neuroengineering. Each student will also be required to develop a research statement on her/his own research interest. It is expected that students will improve her/his writing skills for proposal/research statement development with case studies, group discussions, and individualized feedbacks on students' own writing and presentation. This course will help students to develop practical skills addressing real world problems in neuroengineering.

42-667 Biofabrication and Bioprinting

Spring: 12 units

This laboratory course is designed to introduce students to and give them hands-on experience using methods that are used to fabricate scaffolds that are often used in tissue engineering, drug delivery, and some medical devices. Methods that will be taught include plastic FDM (filament deposition methods) to 3d print thermoplastic materials and molds for casting soft hydrogel materials, as well as 3d Bioprinting of soft hydrogel materials into a support bath material. This course will include a lecture component to introduce students to the concepts needed to design and fabricate the scaffolds. Lecture topics will include (but are not limited to): chemical and physical properties of biomaterials, CAD, and post-processing methods. There are no pre-requisite courses; however prior introductory lab experience is suggested.

42-668 "Fun"-damentals of MRI and Neuroimaging Analysis

Spring: 9 units

Neuroimaging gives us many ways to learn how the brain operates through various functions and disease states without having to perform any invasive surgery. This course will cover the methodology and analysis of structural magnetic resonance imaging (MRI) and functional MRI in humans and animals. Through lecture, discussion and analysis of sample data, students will understand the (A) history of MRI, (B) physics of MRI, (C) utilization with MRI and other devices used to interpret biological tissue, (D) how to design an fMRI experiment, and (E) analysis techniques in MRI. At the end of the course, students will have strong fundamental MRI and fMRI skillset and gain programming skills in MATLAB and learn other tools like SPM to process MRI and fMRI datasets in appropriate software packaging.

42-669 Energy Applications in Biology and Medicine

Spring: 12 units

This course covers a wide range of energy-based applications in biology and medicine, such as cancer treatments by cryosurgery (freezing), thermal ablation (heating), photodynamic therapy (light-activated drugs), and irreversible electroporation (a non-thermal electrical application). This course also covers thermal regulation in humans and other mammals, as well as cryopreservation (low-temperature preservation) of tissues and organs for the benefit of organ banking and transplant medicine. The course combines lectures and individual assignments relating to the underlying principles of engineering, with teamwork on open-ended projects relating to concurrent challenges at the convergence of engineering and medical sciences. The course plan assumes a mastery of the fundamentals of heat transfer at the undergraduate level.

42-670 Special Topics: Biomaterial Host Interactions in Regenerative Medicine

Fall: 12 units

Special Topics: This course will provide students with hands-on experience in investigating host responses to synthetic and naturally biomaterials used in regenerative medicine applications. Students will gain experience in the analysis of host responses to these biomaterials as well as strategies to control host interaction. Biomaterial biocompatibility, immune interactions, tissue healing and regeneration will be addressed. Students will integrate classroom lectures with laboratory skills evaluating host-material interactions in a laboratory setting. Laboratory characterization techniques will include cell culture techniques, microscopic, cytochemical, immunocytochemical and histological analyses. Prerequisite: junior or senior standing in Biomedical Engineering or consent of the instructor.

42-671 Precision Medicine for Biomedical Engineers

Fall: 9 units

This course explores the opportunities for engineers in precision medicine of complex medical disorders. Students will interact with clinical practitioners and investigate the technological challenges that face these practitioners. The course will focus on common complex conditions and diseases such as inflammatory bowel disease (IBD), pancreatitis, diabetes mellitus and obesity, rheumatoid arthritis, multiple sclerosis, pain syndrome and pharmacogenetics. Improvement in care of these conditions requires a reverse engineering approach, and new tools because of the complexity and unpredictability of clinical course and best treatments on a case-by-case basis. Currently, the cost of medications for these conditions in Pittsburgh alone is on the order of 1 billion, with a large percent of patients receiving less than optimal treatment because of lack of precision medicine tools. The course includes introduction to medical genetics, biomarkers of disease, health records, disease modeling, outcome predictions, therapies, remote monitoring and smart applications. Special lectures on health economics and career opportunities are also planned. Each session will include didactic lectures, workshops and development of applications. Specific engineering topics which may be relevant to each of these specialties as well as topics which span many specialties (for example biodetectors, computational biology, bioinformatics, UI/UX, gaming ideas to connect patients to products, integrated applications) will be presented by various faculty members of the CMU biomedical engineering and other dept. and UPMC/UPitt faculty. Students will gain experience exploring genetic variants associated with common diseases, including the opportunity to explore their own DNA. Instructors: David C. Whitcomb, MD, PhD (UPMC) Philip Empey, PharmD, PhD (UPMC)

42-672 Fundamentals of Biomedical Imaging and Image Analysis

Spring: 12 units

This course introduces fundamentals of biological and medical imaging modalities and related image analysis techniques. It is organized into three units. The first unit introduces fundamental principles of biological imaging modalities, such as fluorescence microscopy, super-resolution microscopy, and electron microscopy. These modalities are used to visualize and record biological structures and processes at the molecular and cellular levels. The second unit introduces fundamental principles of imaging modalities, such as magnetic resonance imaging, x-ray computed tomography, and ultrasound. These modalities are used to visualize and record medical structures and processes at the tissue and organ levels. Recent developments in convergence of biological and medical imaging are briefly discussed. The third section introduces fundamentals of computational techniques used for analyzing and understanding biological and medical images, such as deconvolution, registration, segmentation, tracking, and pattern recognition. The introduction to these topics will draw on concepts and techniques from several related fields, including physics, statistics, signal processing, computer vision, and machine learning. As part of the course, students will complete several independent projects. Students will also have the opportunity to visit laboratories to see some of the actual biomedical imaging devices in action. Prerequisites: 18-290 Signals and Systems or permission of the instructor. Proficiency in basic programming is expected. Knowledge of image processing, computer vision, and/or MATLAB is helpful but not essential.

42-673 Special Topics: Stem Cell Engineering

Intermittent: 9 units

Special Topics: This course will give an overview over milestones of stem cell research and will expose students to current topics at the frontier of this field. It will introduce students to the different types of stem cells as well as environmental factors and signals that are implicated in regulating stem cell fate. The course will highlight techniques for engineering of stem cells and their micro-environment. It will evaluate the use of stem cells for tissue engineering and therapies. Emphasis will be placed on discussions of current research areas and papers in this rapidly evolving field. Students will pick a class-related topic of interest, perform a thorough literature search, and present their findings as a written report as well as a paper review and a lecture. Lectures and discussions will be complemented by practical lab sessions, including: stem cell harvesting and culture, neural stem cell transfection, differentiation assays, and immunostaining, polymeric microcapsules as advanced culture systems, and stem cell integration in mouse brain tissue. The class is designed for graduate students and upper undergraduates with a strong interest in stem cell biology, and the desire to actively contribute to discussions in the class.

42-674 Special Topics: Engineering for Survival: ICU Medicine

Intermittent: 9 units

Special Topics: Engineering for Survival: ICU Medicine The overall learning objective of this class is to expose students to acute care medicine and the fundamentals of acute illness. The lectures review the structure and function of different body systems. Typical modes of failure (disease) are then described and illustrated with examples using actual de-identified cases based on over 30 years of experiences in the intensive care unit (ICU) by Dr. Rosenbloom. Field trips are made to a local critical care and emergency medicine simulation facility at the University of Pittsburgh. An optional opportunity to participate in ICU rounds is also available. Requirements: Junior standing and higher

42-675 Fundamentals of Computational Biomedical Engineering

Fall: 12 units

This goal of this course is to enable students with little or no programming background to use computational methods to solve basic biomedical engineering problems. Students will use MATLAB to solve linear systems of equations, model fit using least squares techniques (linear and nonlinear), interpolate data, perform numerical integration and differentiation, solve differential equations, and visualize data. Specific examples for each topic will be drawn from different areas of biomedical engineering, such as bioimaging and signal processing, biomechanics, biomaterials, and cellular and biomolecular technology.

42-676 Bio-nanotechnology: Principles and Applications

Fall: 9 units

Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy. This class is open for both undergraduate (junior/senior) and graduate students.

42-678 Medical Device Innovation and Realization

Spring: 12 units

The increasing pace of medical discoveries and emerging technologies presents a unique and exciting time for medical devices. Medical devices range from biomaterials that stimulate the body to repair itself to drug eluting stents to robotic surgical systems. Because they seek to improve and prolong human health, there are unique requirements and challenges for medical device development compared to most other industries. This class will look at how medical device innovation is currently practiced as well as the drivers which govern it, such as the FDA, intellectual property, reimbursement, and funding. By the end of this course, students should be able to: (1) obtain a broad understanding of medical devices; (2) identify new product opportunities; (3) understand the drivers that affect medical device development; and (4) develop strategies to address those drivers within the overall medical device development plan.

42-681 Disease Models for Therapeutic Discovery

Spring: 9 units

One of the key challenges in the fields of tissue engineering and disease modelling is a disconnect between the use of robust bioengineering tools and our limited understanding of pathobiology. The future of these fields depends on biomedical engineers using their technical skill sets to study normal physiology and disease mechanisms. In this class, we will explore current state-of-the-art methods for creating tissue and disease models, including: 2D/3D tissue cultures, bioreactors, organs-on-a-chip, microfluidic models, disease-in-a-dish models (with discussions on coupling multiple tissue systems), animal models of disease, and CRISPR/CAS9. The first few weeks of the semester will focus on learning the state-of-the-art methods with 1 exam as an assessment. The rest of the class will focus on specific disease modules with journal reviews and experts sharing their research on disease models with the class. For assessment, students will read 1 journal article each week and provide a brief critique. In addition, they will write a grant and present to the class methods for creating a disease model of their choice. At the end of the class, students will be able to critically assess and design models of normal and pathobiological disease mechanisms. Prior knowledge of basic physiology is required.

42-682 Bioinstrumentation

Intermittent: 12 units

This course aims to build concepts and skills in electronics for the design and construction of instruments for biomedical applications. The course uses a flipped, fast-paced format to cover a range of electronic components and circuits, including resistors, capacitors, transistors, sensors, actuators, amplifiers, signal filters, and microcontrollers, through lectures, tutorials, weekly lab projects, and term projects. Students, with or without a background in electronics, will gain hands-on skills to build functional instruments for physiological measurements such as temperature, gas concentration, blood pressure, and EKG signals.

42-683 Introduction to Machine Learning for Biomedical Engineers

Fall: 9 units

This course introduces fundamental concepts, methods and applications in machine learning and datamining. We will cover topics such as parametric and non-parametric learning algorithms, support vector machines, neural networks, clustering, and principal components analysis. The emphasis will be on learning high-level concepts behind machine learning algorithms, and applying them to biomedical-related problems. This course is intended for advanced undergraduate and graduate students in Biomedical Engineering or related disciplines. Students should have experience with high-level programming language such as Matlab, basic familiarity with probability, statistics and linear algebra, and should be comfortable with manipulating vectors and matrices.

42-684 Principles of Immunoengineering and Development of Immunotherapy Drugs

Fall: 9 units

This course will provide context for the application of engineering principles to modulate the immune system to approaches problems in human health. Basic understanding of the components and function of the innate and adaptive immune system. Students will leave with a basic understanding of immunology and of the engineering techniques used to develop and characterize immunotherapy systems. Where appropriate, we will discuss how immunoengineering fits into other disciplines of engineering such as mechanical, chemical, and materials science. Because the purpose of immunoengineering is disease treatment, we will discuss the therapy pipeline, development of clinical trials and the FDA approval process. Immunotherapy will also be assessed within different disease contexts including cancer, infectious disease, allergies, prosthetics and implants, neuro and musculoskeletal disorders.

42-685 Biostatistics

Spring: 9 units

This course introduces statistical methods for making inferences in engineering, biology and medicine. Students will learn how to select the most appropriate methods, how to apply these methods to actual data, and how to read and interpret computer output from a commonly used statistical package. The topics covered are descriptive statistics; elementary probability; discrete and continuous random variables and their distributions; hypothesis testing involving interval (continuous and discrete) and categorical (nominal and ordinal) variables, for two and three or more treatments; simple and multiple linear regression; time-series analysis; clustering and classification; and time-to-event (survival) analysis. Students will also learn how to write the statistical component of a "Results" section for a scientific paper and learn about the limitations of the statistical analyses. Basic familiarity with probability and probability distribution preferred but not required.

42-687 AI Applications in BME

Spring: 12 units

This course provides hands-on experience in applying the fundamentals of artificial intelligence/machine learning (AI/ML) to problems in a variety of biomedical research areas and applications. Students will work in teams to design, develop, and evaluate an AI/ML system to achieve one or more of the following goals: identifying patterns in the data, modeling the input-output relationships and/or classifying data into distinct categories. The datasets for this course will be drawn from different BME-related areas provided by biomedical researchers, clinicians, and other publicly available sources. In addition to the project work, the course will discuss issues that are specific to the development and implementation of AI algorithms in medical settings. This includes FDA approval, human clinical trials, the Health Insurance Portability and Accountability Act, and medical ethics. This computational project-based course is available to any student who has completed Introduction to Machine Learning course.

42-688 Introduction to Neural Engineering

Intermittent: 12 units

Neural engineering sits at the interface between neuroscience and engineering, applying classical engineering approaches and principles to understand the nervous system and its function. Modern neural engineering techniques have been used to measure neural activity using tools based on light, electricity, and magnetism. The same tools for measurement can be redirected to modulate neural activity, and manipulate how an organism perceives, thinks, and acts. The course objectives are to familiarize students with a range of neural engineering approaches to investigating and intervening in the nervous system, emphasizing quantitative understanding and fundamental engineering concepts. The course will pair lectures and discussion with projects involving real neural data (Matlab-based exercises). Example projects could include finding visual responses in EEG data, or determining how groups of individual neurons interact based on spiking data. Overall, the goal is to give the student a deep understanding of select topics in neuroscience and the application of quantitative neural engineering approaches to these topics. This course is intended for advanced undergraduate and entering graduate students. Familiarity with linear algebra, signal processing, and introductory Matlab programming is helpful. This course is suitable for students coming from diverse backgrounds: (1) Students with non-engineering backgrounds seeking quantitative skills, and wanting to learn an engineering approach to neuroscience problems, and (2) students with engineering or other quantitative backgrounds who are seeking ways to apply their skills to scientific questions in neuroscience.

42-689 Introduction to Biomedical Imaging

Spring: 9 units

The field of medical imaging describes methods of seeing the interior of the human body, as well as visual representation of tissue and organ function. The materials covered in this course will give an overview of existing medical imaging devices used in a clinical and pre-clinical setting. The course presents the principles of medical imaging technologies, explaining the mathematical and physical principles, as well as describing the fundamental aspects of instrumentation design. Students will gain a thorough understanding of how these methods are used to image morphological and physiological features. Imaging methods will include Ultrasound, X-ray, computed tomography (CT), and magnetic resonance imaging (MRI), as well as optical methods. For each method, the fundamental imaging principles will be discussed, and examples of clinical applications will be presented. No prior knowledge of imaging methods is required.

42-690 BME in Everyday Life

Intermittent: 9 units

This course focuses on how biomedical engineering technologies are used in everyday life. The objective is to develop an understanding of the clinical need for these technologies, and past and current solutions to meet these clinical needs. Topics covered include artificial organs, tissue engineering, brain-control interfaces, and immunoengineering. For each medical condition being addressed, biology physiology, and anatomy concepts will be applied in the context of biomedical engineering technology. This course is suitable for non-engineering majors who have an interest in biomedical engineering.

42-691 Biomechanics of Human Movement

Spring: 12 units

This course provides an overview of the mechanical principles underlying human movement biomechanics and the experimental and modeling techniques used to study it. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulations, and imaging-based biomechanics. Homework and final class projects will emphasize applications of movement biomechanics in orthopedics, rehabilitation, and sports.

Prerequisites: 21-260 and 24-351

42-692 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology

Fall: 12 units

This course provides an introduction to modern nanoscale manufacturing using structural DNA nanotechnology. This DNA-based approach to manufacturing has much in common with other fabrication methods in micro- and nano-engineering: computer aided design tools are necessary for device design and resulting structures can only be seen using advanced microscopy. However, instead of machining larger materials down to micro- and nanostructures, DNA origami is fabricated using a "bottom up" approach for self-assembling individual oligonucleotides into 2D and 3D nanostructures. Resulting structures can be designed to have novel mechanical and electrical properties and have applications as broad-ranging as medicine, biological computing, and energy systems. The course will include lectures, hands-on physical modeling, homework problems, 3D modeling of DNA origami using caDNA and CANDO software, and student team projects and presentations.

42-693 Special Topics in Integrated Systems Technology: Micro/Nano Biomedical Devices

Fall: 12 units

Biomedical devices constantly call for innovations. Micro/nano fabrication not only miniaturizes devices and instruments, but also can enable new biomedical devices and significantly boost device performance. This course introduces fundamental micro/nano fabrication technologies and related materials of biomedical devices. The biomedical background and design principles of various biomedical devices will be presented. Both diagnostic and therapeutic devices will be discussed, including point-of-care diagnostic devices, biosensors, DNA sequencers, medical implants, prosthetic devices, drug delivery systems, medical robots, etc.

42-694 Engineering Principles of Medical Devices

Intermittent: 9 units

Medical devices are apparatuses widely used in diagnosis, treatment and prevention of human diseases. The invention and adoption of medical devices is one of the major driving forces for the revolution in modern healthcare. This course takes a systematic and quantitative approach for the design and implementation of medical devices. We will mainly focus on three major medical device categories: bioelectrical devices, biomechanical devices, and medical devices enabled by emerging technologies. For each category, domain knowledge and fundamental principles will be introduced, and detailed design, implementation, and performance analysis will be studied. Analytical equations and simulation tools will be used when appropriate. The course will prepare students with a solid foundation to further study, research, and work in medical device related fields. Pre-requisite or Co-requisite: 42-202 and (21-120 or 21-122 or 21-259) and (33-141 or 33-142) or permission of instructor

42-696 Special Topics: Wearable Health Technologies

Spring: 12 units

This course will provide an overview of emerging wearable health technologies and give students hands-on experience in solving ongoing technical challenges. The wearable sensing field is experiencing explosive growth, with exciting applications in medicine. New lightweight devices will make it easier to monitor health conditions in real time, automatically import data into health informatics systems, and provide haptic feedback with humans in the loop. We will review several aspects of these technologies, including hardware, software, user experience, communication networks, applications, and big data analytics. Students will be paired with a company for a semester-long project that tackles timely computational challenges. Programming experience, in any language, is a pre-requisite.

42-713 Applied Nanoscience and Nanotechnology

Fall and Spring: 12 units

Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterization techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-737 Biomedical Optical Imaging

Fall: 12 units

Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants.

42-772 Special Topics: Applied Nanoscience and Nanotechnology

Fall: 12 units

Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterization techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nano materials in cancer therapy. Pre-requisite: Graduate standing. College level chemistry or physical chemistry, and thermodynamics.

42-774 Special Topics: Introduction to Biophotonics

Fall: 12 units

Biophotonics, or biomedical optics, is a field dealing with the application of optical science and imaging technology to biomedical problems, including clinical applications. The course introduces basic concepts in electromagnetism and light tissue interactions, including optical properties of tissue, absorption, fluorescence, and light scattering. Imaging methods will be described, including fluorescence imaging, Raman spectroscopy, optical coherence tomography, diffuse optical spectroscopy, and photoacoustic tomography. The basic physics and engineering of each imaging technique are emphasized. Their relevance to human disease diagnostic and clinical applications will be included, such as breast cancer imaging and monitoring, 3D retinal imaging, ways of non-invasive tumor detection, as well as functional brain imaging in infants. Pre-requisite: Graduate standing. College level physics covering electromagnetism and optics or permission of the instructor.

42-783 Neural Engineering Laboratory

Intermittent: 12 units

Neural engineering applies classic engineering approaches and principles to understand the nervous system and its function. The measurement of neural activity involves a number of basic tools that have evolved over decades to sense the activity of neurons (individual neurons, populations of neurons and nerve fibers) or activity that is related to neurons (such as the oxygenation of blood in the brain). To intervene in the nervous system, a comparable set of tools have evolved to change neural activity locally or globally, on short and long time scales. The successful application of these methods to measure and manipulate neural activity requires both a basic science and engineering understanding of the principles behind their action, along with practical experience in applying them in real-world settings. This laboratory course will pair lectures with laboratory exercises to gain a deep understanding of the tools we use to measure and manipulate neural activity, as well as the analytic approaches to this data. It will involve both building and diagnosing recording hardware, experimental data collection, data analysis in Matlab or Python, and scientific writing. Overall, the goal is to provide students with a deep understanding of the methods for acquiring experimental data in neuroscience. Familiarity with signal processing and introductory Matlab or Python programming is helpful. This course is suitable for students from diverse backgrounds: (1) Students with experimental backgrounds seeking a range of hands-on experience in different experimental settings and a deeper understanding of different experimental methods, and (2) students with engineering and other quantitative backgrounds seeking exposure to experimental data collection methods and practices.

42-880 Biomaterials

Fall: 9 units

This course is currently only for those enrolled in the 3D Biofabrication and Bioprinting Certificate program. Understanding the fundamentals of biomaterials structure-function relationships pertaining to material functions and to cell and tissue environments will be a prime goal. The course will be composed of lectures, readings, projects and technical writing assignments. The synthesis, characterization and functional properties of organic and inorganic biomaterials and the processes involved in their use in tissue engineering and regenerative medicine will be discussed. Fundamental issues related to the utility of biomaterials, including biomechanics, transport, degradability, biointerfaces and biocompatibility, stability, fate in the body will be covered, along with some of the basic approaches to characterization. Clinical applications for biomaterials and new directions in design and synthesis to achieve better biocompatibility will be emphasized.

Department of Chemical Engineering

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Chemical Engineering is a broad discipline that combines chemistry, mathematics, physics and biology with its own unique principles of *chemical engineering science and process systems engineering* to develop new products and manufacturing processes. Chemical engineering science refers to the material properties and models that help the chemical engineer understand and predict the transformation of chemical compounds at all stages of their conversion from raw materials to value added products. Process systems engineering provides methodologies for the systematic design, optimization, control, operation and analysis of a system of operations by which a product is manufactured, as well as the economic, safety and environmental assessment of these processes.

Modern chemical engineering practice brings together a deep understanding of molecular properties and process design to not only develop more energy-efficient and sustainable manufacturing processes for currently existing products but also to develop new consumer and industrial products that provide enhanced functionality while making more efficient use of resources. As a result, the Chemical Engineering profession offers challenging and well-compensated careers in industries across the economy. Nearly all aspects of modern life use the products of chemical engineering. The pharmaceutical industry recruits chemical engineers to use their knowledge of chemical reaction engineering and separation processes to produce pure and effective pharmaceutical agents and drug delivery systems, and the biopharmaceutical industry attracts chemical engineers who can apply this expertise to biomanufacturing systems based on microbiology and biochemistry. In the chemical and energy sectors, chemical engineers develop catalysts and processes to improve yields in the production of commodity and specialty chemicals and petroleum-based fuels, and they develop new battery systems, fuel cells and biofuels to help build the renewable energy economy. Material manufacturers hire chemical engineers to develop large scale processes to synthesize polymers as resins for formulated products or as fabricated device components. The semiconductor industry seeks the chemical processing expertise of chemical engineers to manufacture chips, integrated circuits, or photovoltaic cells. Chemical engineers in the consumer products industries use their knowledge of chemical transformations to formulate and manufacture nearly all the products that people use in their everyday lives. Consulting companies seek chemical engineers for evaluation of the economic feasibility of industrial projects and to develop software for the design, analysis and operation of manufacturing processes. Finally, the curricular emphasis on the analysis and optimization of complex systems makes Chemical Engineering an excellent preparatory major for students interested in medical or business schools.

The Chemical Engineering curriculum develops deep problem solving skills through challenging, open-ended problems in chemical engineering science, process systems engineering, process system design and product design. Computing is integrated throughout the curriculum. The department's Gary J. Powers Educational Computer Lab supports extensive use of mathematical modeling and simulation software. Students in the Robert Rothfus Laboratory and Lubrizol Analytical Laboratory learn to use computerized data acquisition and control systems as they develop experimental tests of chemical engineering theory or process design alternatives. With its focus on complex chemical and biochemical processes, Chemical Engineering is a natural pairing with the Additional Major in Biomedical Engineering or the Biomedical Engineering minor. Chemical Engineering students pursue many different minors. It is particularly well aligned with the CIT Designated Minor in Colloids, Polymers and Surfaces and the University's Minor in Environmental and Sustainability Studies.

Program Educational Objectives and Student Outcomes

Program Educational Objectives

The Carnegie Mellon University Chemical Engineering Bachelor of Science degree program strives to produce graduates who:

- possess deep knowledge of chemical engineering fundamentals and the ability to combine them with advanced modeling and computational strategies to solve complex problems;
- strive for excellence in their professional activities, with a commitment to safety and ethical practices;

- understand the impact of their work in a global, economic, environmental, and societal context, which includes valuing the perspective of people with diverse backgrounds and experiences;
- are excellent communicators;
- excel both as leaders and as members of working teams; and
- are well prepared for immediate success in either professional employment or advanced education.

Learning Outcomes

Students who complete the Bachelor of Science in Chemical Engineering at Carnegie Mellon University will acquire:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics;
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors;
- an ability to communicate effectively with a range of audiences;
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts;
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives;
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions; and
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

The department offers a number of special programs for students majoring in Chemical Engineering. In addition to the additional majors offered by the College of Engineering such as Biomedical Engineering and Engineering & Public Policy, students may choose from a variety of minors in technical areas offered by the College of Engineering. Undergraduate research projects are also available in the areas of bioengineering, complex fluids engineering, environmental engineering, process systems engineering, and catalysis & surface science. The department offers the Chemical Engineering Summer Scholars (ChESS) program to support undergraduate research within the department. The department distributes application procedures to Chemical Engineering majors during the spring semester.

Students may participate in study abroad programs during their Junior year. In addition to the University Study Abroad programs, the department provides its own exchange programs with: RWTH Aachen in Germany, Imperial College in London, Great Britain, Universidad Nacional del Litoral in Argentina, and Yonsei University in Seoul, Korea. A summer exchange program in Dortmund, Germany is also available. Students may also participate in Practical Internships for Senior Chemical Engineering Students (PISCES), a one-year industrial internship program offered between the Junior and Senior years. Finally, qualified students may enroll in our Master of Chemical Engineering program. This degree is typically completed in the fifth year. However, depending on the number of advanced placement courses and course load at Carnegie Mellon, this degree could be awarded during the B.S. graduation, or after one additional semester.

Curriculum for Class of 2024

Minimum units required for B.S. in Chemical Engineering 389

The program in chemical engineering within the Department of Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

FIRST YEAR

| Fall | | Units |
|--------|--------------------------------------|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 76-xxx | Designated Writing/Expression Course | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 06-100 | Introduction to Chemical Engineering | 12 |

| | | |
|--------|--|-----------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| | | 44 |
| Spring | | Units |
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Introductory Engineering Elective (other than ChE) | 12 |
| 33-141 | Physics I for Engineering Students | 12 |
| xx-xxx | General Education Course | 9 |
| | | 43 |

SECOND YEAR

| | | |
|-----------|--|--------------|
| Fall | | Units |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-254 | Linear Algebra and Vector Calculus for Engineers | |
| 06-223 | Chemical Engineering Thermodynamics | 12 |
| 06-222 | Sophomore Chemical Engineering Seminar | 1 |
| 09-106 | Modern Chemistry II | 10 |
| xx-xxx | Computer Sci./Physics II * | 10-12 |
| xx-xxx | General Education Course | 9 |
| 39-210 | Experiential Learning I | 0 |
| | | 52-54 |

| | | |
|--------|---|--------------|
| Spring | | Units |
| 06-261 | Fluid Mechanics | 9 |
| 06-262 | Mathematical Methods of Chemical Engineering | 12 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| xx-xxx | Physics II/Computer Sci. * | 12-10 |
| xx-xxx | General Education Course | 9 |
| 39-220 | Experiential Learning II | 0 |
| | | 54-52 |

* Computer Science/Physics II: Students should complete 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science as well as 33-142 Physics II for Engineering and Physics Students by the end of the Sophomore year. The recommended sequence is 33-141 /33-142 for engineering students, however, 33-151/ 33-152 will also meet the CIT Physics requirement.

For those students who have not taken 06-100 as one of the two Introductory Engineering Electives, 06-100 should be taken in the Fall Semester of the Sophomore year. The General Education Course normally taken during that semester may be postponed until the Junior year. These students should consult with their faculty advisors as soon as possible.

At the end of the Sophomore year, a student should have completed the following required basic science and computer science courses:

| | | |
|-----------|--|-------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 15-110 | Principles of Computing | 10-12 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 33-141 | Physics I for Engineering Students | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 99-10x | Computing @ Carnegie Mellon | 3 |

THIRD YEAR

| | | |
|-----------|---|--------------|
| Fall | | Units |
| 06-325 | Numerical Methods and Machine Learning for Chemical Engineering | 6 |
| 06-326 | Optimization Modeling and Algorithms | 6 |
| 06-322 | Junior Chemical Engineering Seminar ** | 2 |
| 06-323 | Heat and Mass Transfer | 9 |
| 09-217 | Organic Chemistry I | 9-10 |
| or 09-219 | Modern Organic Chemistry | |
| 06-310 | Molecular Foundations of Chemical Engineering | 9 |
| xx-xxx | General Education Course | 9 |
| 39-310 | Experiential Learning III | 0 |
| | | 50-51 |

| | | |
|--------|---|-----------|
| Spring | | Units |
| 06-361 | Unit Operations of Chemical Engineering | 9 |
| 06-363 | Transport Process Laboratory | 9 |
| 06-364 | Chemical Reaction Engineering | 9 |
| xx-xxx | Advanced Chemistry Elective**/** | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 54 |

FOURTH YEAR

| | | |
|--------|---------------------------------|-----------|
| Fall | | Units |
| 06-421 | Chemical Process Systems Design | 12 |
| 06-423 | Unit Operations Laboratory | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 48 |

| | | |
|--------|--------------------------------------|-----------|
| Spring | | Units |
| 06-463 | Chemical Product Design **** | 9 |
| 06-464 | Chemical Engineering Process Control | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 45 |

** For students pursuing a Chemical Engineering/Biomedical Engineering double major, the Chemical Engineering Junior Seminar course 06-322 Junior Chemical Engineering Seminar is replaced by the Biomedical Engineering course Professional Issues in Biomedical Engineering 42-201 Professional Issues in Biomedical Engineering.

Students pursuing a Chemical Engineering/Engineering and Public Policy double major are waived from taking the Advanced Chemistry Elective. They will take 36-220.

*** **Advanced Chemistry Elective** may be any technical course offered by the Department of Chemistry for at least 9 units at the 200-level or above (such as Organic chemistry 2), or one of the following: 03-232 Biochemistry I, 06-607 Physical Chemistry of Colloids and Surfaces, or 06-609/09-509 Physical Chemistry of Macromolecules.

Students may petition the Undergraduate Committee to approve other chemistry-focused courses offered by other departments on a case-by-case basis.

**** 06-463 Chemical Product Design for Classes of 2024 and beyond is a 9 unit course. For Classes up to 2023, it is a 6 unit course. The 06-463 Chemical Product Design requirement is waived for students completing 42-401 Foundation of BME Design (6 units, fall) AND 42-402 BME Design Project (9 units, spring).

NOTES:

- In addition to the graduation requirement of an overall QPA of 2.0 (not counting the First Year), the Department of Chemical Engineering requires a cumulative QPA of 2.0 in all chemical engineering courses (all those numbered 06-xxx).
- Minimum number of units required for graduation: 389.
- All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
- A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.
- Overloads are permitted only for students maintaining a QPA of 3.5 or better during the preceding semester.
- Electives: To obtain a Bachelor of Science degree in Chemical Engineering, students must complete 06-100 and one other Introductory Engineering Elective. There are also five Unrestricted Electives. Students must discuss choice of electives with their faculty advisors.
- Undergraduate Research: Independent research projects are available by arrangement with a faculty advisor. Many students conduct these research projects for elective credit by enrolling in 06-200, 06-300,

or 06-400 (Sophomore, Junior, or Senior Research Projects) or 39-500 CIT Honors Research Project for eligible Seniors.

- Advanced undergraduates may also take Chemical Engineering graduate courses (600+ level).

Curriculum for Class of 2025 and Beyond

Minimum units required for B.S. in Chemical Engineering 391

The program in chemical engineering within the Department of Chemical Engineering is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

First Year

| Fall | | Units |
|--------|--------------------------------------|-----------|
| 21-120 | Differential and Integral Calculus | 10 |
| 76-xxx | Designated Writing/Expression Course | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 06-100 | Introduction to Chemical Engineering | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| | | 44 |

| Spring | | Units |
|--------|--|-----------|
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Introductory Engineering Elective (other than ChE) | 12 |
| 33-141 | Physics I for Engineering Students | 12 |
| xx-xxx | General Education Course | 9 |
| | | 43 |

Second Year

| Fall | | Units |
|--------|--|--------------|
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 06-223 | Chemical Engineering Thermodynamics | 12 |
| 06-222 | Sophomore Chemical Engineering Seminar | 1 |
| 09-106 | Modern Chemistry II | 10 |
| xx-xxx | Computer Sci./Physics II * | 10-12 |
| xx-xxx | General Education Course | 9 |
| 39-210 | Experiential Learning I | 0 |
| | | 53-55 |

| Spring | | Units |
|--------|---|--------------|
| 06-261 | Fluid Mechanics | 9 |
| 06-262 | Mathematical Methods of Chemical Engineering | 12 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| xx-xxx | Physics II/Computer Sci. * | 12-10 |
| xx-xxx | General Education Course | 9 |
| 39-220 | Experiential Learning II | 0 |
| | | 54-52 |

* Computer Science/Physics II: Students should complete 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science as well as 33-142 Physics II for Engineering and Physics Students by the end of the Sophomore year. The recommended sequence is 33-141 /33-142 for engineering students, however, 33-151/ 33-152 will also meet the CIT Physics requirement.

For those students who have not taken 06-100 as one of the two Introductory Engineering Electives, 06-100 should be taken in the Fall Semester of the Sophomore year. The General Education Course normally taken during that semester may be postponed until the Junior year. These students should consult with their faculty advisors as soon as possible.

At the end of the Sophomore year, a student should have completed the following required basic science and computer science courses:

| | | |
|--------|---|-------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 15-110 | Principles of Computing | 10-12 |

| | | |
|-----------|--|----|
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 33-141 | Physics I for Engineering Students | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 99-10x | Computing @ Carnegie Mellon | 3 |

Third Year

| Fall | | Units |
|-----------|---|--------------|
| 06-325 | Numerical Methods and Machine Learning for Chemical Engineering | 6 |
| 06-326 | Optimization Modeling and Algorithms | 6 |
| 06-322 | Junior Chemical Engineering Seminar ** | 2 |
| 06-323 | Heat and Mass Transfer | 9 |
| 09-217 | Organic Chemistry I | 9-10 |
| or 09-219 | Modern Organic Chemistry | |
| 06-310 | Molecular Foundations of Chemical Engineering | 9 |
| xx-xxx | General Education Course | 9 |
| 39-310 | Experiential Learning III | 0 |
| | | 50-51 |

| Spring | | Units |
|--------|---|-----------|
| 06-361 | Unit Operations of Chemical Engineering | 9 |
| 06-363 | Transport Process Laboratory | 9 |
| 06-364 | Chemical Reaction Engineering | 9 |
| xx-xxx | Advanced Chemistry Elective**/** | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 54 |

Fourth Year

| Fall | | Units |
|--------|---------------------------------|-----------|
| 06-421 | Chemical Process Systems Design | 12 |
| 06-423 | Unit Operations Laboratory | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 48 |

| Spring | | Units |
|--------|--------------------------------------|-----------|
| 06-463 | Chemical Product Design **** | 9 |
| 06-464 | Chemical Engineering Process Control | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | Unrestricted Elective | 9 |
| xx-xxx | General Education Course | 9 |
| | | 45 |

** For students pursuing a Chemical Engineering/Biomedical Engineering double major, the Chemical Engineering Junior Seminar course 06-322 Junior Chemical Engineering Seminar is replaced by the Biomedical Engineering course Professional Issues in Biomedical Engineering 42-201 Professional Issues in Biomedical Engineering. Students pursuing a Chemical Engineering/Engineering and Public Policy double major are waived from taking the Advanced Chemistry Elective. They will take 36-220.

*** **Advanced Chemistry Elective** may be any technical course offered by the Department of Chemistry for at least 9 units at the 200-level or above (such as Organic chemistry 2), or one of the following: 03-232 Biochemistry, 06-607 Physical Chemistry of Colloids and Surfaces, or 06-609/09-509 Physical Chemistry of Macromolecules.

Students may petition the Undergraduate Committee to approve other chemistry-focused courses offered by other departments on a case-by-case basis.

**** 06-463 Chemical Product Design for Classes of 2024 and beyond is a 9 unit course. For Classes up to 2023, it is a 6 unit course. The 06-463 Chemical Product Design requirement is waived for students completing 42-401 Foundations of Biomedical Engineering Design (6 units, fall) AND 42-402 Biomedical Engineering Design Project (9 units, spring).

Notes:

- In addition to the graduation requirement of an overall QPA of 2.0 (not counting the First Year), the Department of Chemical Engineering

requires a cumulative QPA of 2.0 in all chemical engineering courses (all those numbered 06-xxx).

2. Minimum number of units required for graduation: 391.
3. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
4. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.
5. Overloads are permitted only for students maintaining a QPA of 3.5 or better during the preceding semester.
6. Electives: To obtain a Bachelor of Science degree in Chemical Engineering, students must complete 06-100 and one other Introductory Engineering Elective. There are also five Unrestricted Electives. Students must discuss choice of electives with their faculty advisors.
7. Undergraduate Research: Independent research projects are available by arrangement with a faculty advisor. Many students conduct these research projects for elective credit by enrolling in 06-200, 06-300, or 06-400 (Sophomore, Junior, or Senior Research Projects) or 39-500 CIT Honors Research Project for eligible Seniors.
8. Advanced undergraduates may also take Chemical Engineering graduate courses (600+ level).

Additional Major in Engineering and Public Policy (EPP)

Students may pursue an additional major in Chemical Engineering and EPP. This double major is built around electives in Social Analysis, Probability and Statistics courses, and projects. Specific course choices should be discussed with a faculty advisor and an EPP advisor.

Additional Major in Engineering Design, Innovation & Entrepreneurship (EDIE)

Students may pursue an additional major in Chemical Engineering and EDIE. Specific course choices should be discussed with a faculty advisor and an EDIE advisor.

Additional Major in Biomedical Engineering (BME)

Students may pursue an additional major in Chemical Engineering and BME. Specific course choices should be discussed with a faculty advisor and a BME advisor.

Minors with a B.S. in Chemical Engineering

Chemical Engineering students are eligible for any CIT Designated Minor. Those minors that are especially well suited to Chemical Engineers include: Additive Manufacturing, Audio Engineering, Biomedical Engineering, Colloids, Polymers & Surfaces, Electronic Materials, Global Engineering, Materials Science and Engineering, Mechanical Behavior of Materials, and Robotics. The minor requirements may be fulfilled with electives. Other minors, such as the Supply Chain Management minor in association with the Tepper School of Business, are also available outside of CIT. These should be discussed with a faculty advisor.

Colloids, Polymers and Surfaces Minor

Professor Robert Tilton, *Director of CPS Minor*
Location: Doherty Hall A207C

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials,

surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor: 45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

| | | |
|---------------|---|---|
| 06-609/09-509 | Physical Chemistry of Macromolecules | 9 |
| 06-607 | Physical Chemistry of Colloids and Surfaces | 9 |
| 06-426 | Experimental Colloid Surface Science | 9 |
| 06-466 | Experimental Polymer Science | 9 |

In addition, the student must take one CPS related elective course from the following list:

| | | |
|--------|---|----|
| 06-612 | Formulation Engineering | 12 |
| 06-610 | Rheology and Structure of Complex Fluids | 9 |
| 09-502 | Organic Chemistry of Polymers | 9 |
| 27-565 | Nanostructured Materials | 9 |
| 27-477 | Introduction to Polymer Science and Engineering | 9 |

Other CPS electives are possible but must be approved by the Director of the CPS minor, Professor Tilton

The Chemical Engineering curriculum develops deep problem solving skills through challenging, open-ended problems in chemical engineering science, process systems engineering, process system design and product design. Computing is integrated throughout the curriculum. The department's Gary J. Powers Educational Computer Lab supports extensive use of mathematical modeling and simulation software. Students in the Robert Rothfus Laboratory and Lubrizol Analytical Laboratory learn to use computerized data acquisition and control systems as they develop experimental tests of chemical engineering theory or process design alternatives. With its focus on complex chemical and biochemical processes, Chemical Engineering is a natural pairing with the Additional Major in Biomedical Engineering or the Biomedical Engineering minor. Chemical Engineering students pursue many different minors. It is particularly well aligned with the CIT Designated Minor in Colloids, Polymers and Surfaces and the University's Minor in Environmental and Sustainability Studies.

Practical Internships for Senior Chemical Engineering Students (PISCES)

Chemical Engineering students may apply in the fall of their Junior year for a salaried, one-year PISCES internship with a partner company. Admitted students begin their internships after completion of the Junior year. Following the internship, students return to complete their Senior year. There are several advantages of a one full-year internship, including the opportunity to gain a breadth of professional experience that is not generally possible in a shorter program, more opportunity to make important contributions to the partner company, and the opportunity to complete Senior year courses in their normal sequence with no need for curriculum rearrangements. Interested students should consult with their faculty advisors.

International Chemical Engineering Exchange Programs

Chemical Engineering students may apply during their Sophomore year to spend their Junior year at RWTH Aachen in Germany, Yonsei University in Seoul, Korea, Universidad Nacional del Litoral in Argentina, or at Imperial College in London, Great Britain. A summer exchange program in Dortmund, Germany is also available. These exchange programs provide a great opportunity for students to obtain international experience while taking courses very similar to those offered at Carnegie Mellon. Students considering any of these programs should consult with their faculty advisors, and students considering the Aachen program in particular are advised to take at least one introductory German course before or during their Sophomore year.

Fifth Year Master of Chemical Engineering (MChE)

The CIT Integrated Masters/Bachelors (IMB) Degree program provides the opportunity for qualified undergraduate students to obtain a master's degree in Chemical Engineering with one or two extra semesters of study. The goal is to deepen our graduates' understanding of the fundamentals of chemical engineering, and to provide them with a broader set of professional skills or to expose them to other technical disciplines.

The MChE program is a 96 unit course work degree aimed at undergraduate students from Carnegie Mellon and candidates from other universities.

Unfortunately, no financial support is available. For Carnegie Mellon students, the degree typically would be completed in their fifth year. Depending on advanced placement and semester overloads, however, CMU students can complete the degree at the time of the B.S. graduation or with one additional semester. All students must have graduate status once they have completed their B.S. degree; beyond eight semesters, degree program students must have full-time graduate student status in at least one (e.g., their final) semester whether or not they have already completed their BS degree. Upon graduating from this program, students seek industrial positions or placement in graduate programs at other universities. Students in the MChE program may apply for the PhD program at Carnegie Mellon University via the normal application process. Their applications are considered alongside all the other applications received that year. If accepted into the PhD program, they enter it after completing the MChE degree.

A minimum of five completed semesters in residence as an undergraduate student and an overall QPA of 3.0 is required for eligibility. Taking the GRE and recommendation letters are not required. The application fee is waived for currently-enrolled undergraduate Chemical Engineering students.

The MChE program differs from the MS program because the MChE program does not require a project report or thesis.

Faculty

SHELLEY ANNA, Professor of Chemical Engineering - Ph.D., Harvard University; Carnegie Mellon, 2003-

JOANNE BECKWITH, Assistant Teaching Professor of Chemical Engineering - Ph.D., University of Michigan; Carnegie Mellon, 2022-

LORENZ T. BIEGLER, Covestro University Professor Professor of Chemical Engineering - Ph.D., University of Wisconsin; Carnegie Mellon, 1981-

DAPHNE WUI YARN CHAN, Assistant Professor of Chemical Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022--

MICHAEL M. DOMACH, Emeritus, Professor of Chemical Engineering - Ph.D., Cornell University; Carnegie Mellon, 1983-

NEIL M. DONAHUE, Lord University Professor of Chemistry and Chemical Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000-

ANDREW J. GELLMAN, Lord Professor of Chemical Engineering - Ph.D., University of California, Berkeley; Carnegie Mellon, 1992-

GABRIEL GOMES, Assistant Professor of Chemistry and Chemical Engineering - Ph.D., Florida State University; Carnegie Mellon, 2022-

HAMISH GORDON, Assistant Professor of Chemical Engineering - Ph.D., University of Oxford; Carnegie Mellon, 2022-

CHRYSANTHOS GOUNARIS, Professor of Chemical Engineering - Ph.D., Princeton University; Carnegie Mellon, 2013-

IGNACIO E. GROSSMANN, R. R. Dean University Professor of Chemical Engineering - Ph.D., Imperial College, University of London; Carnegie Mellon, 1979-

ANNETTE JACOBSON, Emeritus, Teaching Professor of Chemical Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1988-

COTY JEN, Assistant Professor of Chemical Engineering - Ph.D., University of Minnesota; Carnegie Mellon, 2018-

MYUNG S. JHON, Emeritus, Professor of Chemical Engineering - Ph.D., University of Chicago; Carnegie Mellon, 1980-

ADITYA KHAIR, Professor of Chemical Engineering - PhD, California Institute of Technology; Carnegie Mellon, 2010-

JOHN KITCHIN, Professor of Chemical Engineering - Ph.D., University of Delaware; Carnegie Mellon, 2006-

CARL LAIRD, Professor of Chemical Engineering - Ph.D., Carnegie Mellon; Carnegie Mellon, 2021-

TAGBO NIEPA, Associate Professor of Chemical Engineering - Ph.D., Syracuse University; Carnegie Mellon, 2023-

GRIGORIOS PANAGAKOS, Assistant Research Professor - Ph.D., Technical University of Denmark; Carnegie Mellon, 2018-

ANNE SKAJA ROBINSON, Trustee Professor of Chemical Engineering and Department Head - Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019-

JAMES W. SCHNEIDER, Professor of Chemical Engineering - Ph.D., University of Minnesota; Carnegie Mellon, 1999-

PAUL J. SIDES, Emeritus, Professor of Chemical Engineering - Ph.D., University of California, Berkeley; Carnegie Mellon, 1981-

SUSANA C. STEPPAN, Emeritus, Associate Teaching Professor - Ph.D., University of Massachusetts; Carnegie Mellon, 2004-

ROBERT D. TILTON, Chevron Professor of Chemical Engineering - Ph.D., Stanford University; Carnegie Mellon, 1992-

ANA INES TORRES, Assistant Professor of Chemical Engineering - Ph.D., University of Minnesota; Carnegie Mellon, 2022-

ZACHARY ULISSI, Associate Professor of Chemical Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017-

ELIZABETH WAYNE, Assistant Professor of Chemical Engineering and Biomedical Engineering - PhD, Cornell; Carnegie Mellon, 2019-

ARTHUR W. WESTERBERG, Emeritus, University Professor of Chemical Engineering - Ph.D., DIC, Imperial College, University of London; Carnegie Mellon, 1976-

KATHRYN WHITEHEAD, Professor of Chemical Engineering - Ph.D., University of California; Carnegie Mellon, 2012-

B. ERIK YDSTIE, Emeritus, Professor of Chemical Engineering - Ph.D., Imperial College, University of London; Carnegie Mellon, 1992-

Department of Chemical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

06-100 Introduction to Chemical Engineering

Fall and Spring; 12 units

We equip students with creative engineering problem-solving techniques and fundamental chemical engineering material balance skills. Lectures, laboratory experiments, and recitation sessions are designed to provide coordinated training and experience in data analysis, material property estimation for single- and multi-phase systems, basic process flowsheet, reactive and non-reactive mass balances, problem solving strategies and tools, and team dynamics. The course is targeted for CIT First Year students.

06-200 Sophomore Research Project

Fall and Spring

Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-222 Sophomore Chemical Engineering Seminar

Fall; 1 unit

This course provides an overview of the chemical engineering profession. It discusses the rationale for the curriculum, career paths, resume writing, written communication skills, and ethics, and also involves a project on the use and manufacture of chemicals.

06-223 Chemical Engineering Thermodynamics

Fall; 12 units

This course introduces students to thermodynamic state variables and the analysis of phase and chemical equilibrium in single- and multi-component chemical systems. Key topics include application of mass, energy and entropy balance equations to analyze processes with change of state and interconversion of energy between heat and work in open or closed systems; state property changes associated with phase change; equations of state to represent the pressure-volume-temperature relationship for pure materials and mixtures; Gibbs phase rule; phase equilibrium criteria; ideal and non-ideal mixtures; fugacity and prediction of pure liquid vapor pressure; fugacity and activity coefficients to predict multi-component vapor-liquid and liquid-liquid phase equilibrium; analysis of flash and other processes involving multi-component phase change; equilibrium constants and equilibrium conversions in chemically reacting systems.

Prerequisites: 06-100 and (33-141 or 33-121 or 33-151)

06-261 Fluid Mechanics

Spring; 9 units

The principles of fluid mechanics as applied to engineering, including unit operations, are discussed; examples include flow in conduits, process equipment, and commercial pipes, flow around submerged objects, and flow measurement. Microscopic mass and momentum balances are described, including the continuity and Navier-Stokes equations, and modern solution techniques will be explored. Microscopic flow structures will be determined for flow visualization. Boundary layer theory, turbulence, and non-Newtonian fluids are also discussed. A case-study project based on new technological advancements is also required.

Prerequisites: 21-254 and (33-141 or 33-121 or 33-151) and 06-223

06-262 Mathematical Methods of Chemical Engineering

Spring; 12 units

Mathematical techniques are presented as tools for modeling and solving engineering problems. Modeling of steady-state mass and energy balance problems using linear and matrix algebra, including Gaussian elimination, decomposition, and iterative techniques. Modeling of unsteady-state engineering problems using linear and nonlinear differential equations. Analytical techniques, including Laplace transforms, and numerical techniques for the solution of first- and higher-order differential equations and systems of differential equations arising in engineering models. Finally, the modeling of processes affected by chance and subject to experimental error; statistical and regression techniques within the context of experimental design and analysis of experimental data.

Prerequisites: 21-254 and 06-223

06-300 Junior Research Project

Fall and Spring

Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-310 Molecular Foundations of Chemical Engineering

Fall; 9 units

Students will learn to use the tools of molecular engineering that define the modern development of chemical engineering, using a combination of theory and computation. The theme throughout the course is the use of molecular engineering tools to specify alternative compositions and conditions for chemical engineering design. Applications will include the prediction of macroscopic transport properties and equations of state, and the ability to tune them via judicious specification of system composition; rate laws and rate constants for complex reacting systems, including multi-step heterogeneous and homogeneous reactions; and principles of non-covalent association and self-assembly in the context of sustainable chemical engineering product design. Students will investigate contemporary molecular engineering case studies focused on renewable energy, human health or solutions to environmental problems.

Prerequisites: 06-223 and 09-106

06-322 Junior Chemical Engineering Seminar

Fall; 2 units

This course discusses career choices for chemical engineers, professional practice, including alternate career paths, global industry, and graduate studies. It also emphasizes writing, interview skills, and oral presentations. Safety, environmental and ethical issues are illustrated in projects and via invited lectures.

06-323 Heat and Mass Transfer

Fall; 9 units

This course presents the fundamentals of heat and mass transfer, including steady-state and transient heat conduction and molecular diffusion, convection of heat and mass, and thermal radiation, with application to heat and mass transfer processes. Development of dimensionless quantities for engineering analysis is emphasized.

Prerequisites: 06-261 and (21-260 or 06-262) and (33-152 or 33-122 or 33-142)

06-325 Numerical Methods and Machine Learning for Chemical Engineering

Fall; 6 units

This course will focus on applying numerical methods and machine learning to chemical engineering problems. Students will learn how modern programming environments (on laptops and in the cloud) can run python code. Programming concepts such as defining functions and plotting quantities will be reviewed. Students will learn how to apply and debug numerical integration techniques to systems of ODEs. Solving systems of nonlinear equations and black-box optimization will be covered. Machine learning will be introduced starting with the statistics of linear and non-linear regression with regularization. Polynomial fitting and interpolation will be covered. With this base, students will learn how to apply machine learning techniques such as gaussian process regression and neural networks to regression tasks. A small project will be included near the end to encourage creative applications to chemical engineering problems.

Prerequisites: 06-262 and (15-110 or 15-112)

06-326 Optimization Modeling and Algorithms

Fall: 6 units

Formulation and solution of mathematical optimization problems with and without constraints. Objective functions are based on economics or functional specifications. Both discrete and continuous variables are considered.

Prerequisite: 06-262

06-361 Unit Operations of Chemical Engineering

Spring: 9 units

This course comprises many of the standard operations in chemical plants such as gas absorption, heat exchange, distillation and extraction. The design and operation of these devices is emphasized. A project dealing with a novel unit operation is also investigated.

Prerequisite: 06-323

06-363 Transport Process Laboratory

Spring: 9 units

Develop skills for proposing, designing, planning, implementing, interpreting, and communicating the results of experiments in fluid flow and heat and mass transfer. Oral and written reports are required.

Prerequisites: 06-323 and 06-261

06-364 Chemical Reaction Engineering

Spring: 9 units

Fundamental concepts in the kinetic modeling of chemical reactions, the treatment and analysis of rate data. Multiple reactions and reaction mechanisms. Analysis and design of ideal and non-ideal reactor systems. Energy effects and mass transfer in reactor systems. Introductory principles in heterogeneous catalysis.

Prerequisites: 06-310 and 06-323

06-400 Senior Research Project

Fall and Spring

Research projects under the direction of the Chemical Engineering faculty. The nature of the project, the number of units, and the criteria for grading are to be determined between the student and the faculty supervisor. The agreement should then be summarized in a one-page project description for review by the faculty advisor of the student. A final written report or an oral presentation of the results is required.

06-421 Chemical Process Systems Design

Fall: 12 units

Screening of processing alternatives. Computational strategies for preliminary material and energy balances in large chemical processes. Preliminary sizing of process equipment. Cost estimation, economics, and evaluation for chemical plants. Strategies for synthesizing energy networks and separation sequences. Preliminary design of a large industrial project.

Prerequisites: 06-364 and 06-361

06-423 Unit Operations Laboratory

Fall: 9 units

Open-ended laboratory projects illustrate the principles of unit operations in Chemical Engineering. In this course students select, with course staff review, current societal problems to which chemical engineering subject knowledge can be applied. Students work in teams to design and implement an experimental plan to evaluate proposed solutions. Teams must work together to identify constraints and relationships between the unit operations they work on. Students must document implementation feasibility (cost, scheduling, analytic capability, etc.) and clearly identify the criteria and methods for assessing experimental results. Oral and written reports are required.

Prerequisites: 06-361 and 06-364

06-426 Experimental Colloid Surface Science

Fall: 9 units

Laboratory exercises will deal with preparation and stabilization of colloids, flocculation, micellar aggregates, surface tension, contact angle, spreading and adsorption. Basic concepts will be related to practical problems of wetting, lubrication, foaming, adhesion, coatings and corrosion.

Prerequisites: 09-221 and 06-607

06-462 Optimization Modeling and Algorithms

Spring: 6 units

Formulation and solution of mathematical optimization problems with and without constraints. Objective functions are based on economics or functional specifications. Both discrete and continuous variables are considered.

Prerequisite: 06-421

06-463 Chemical Product Design

Spring: 9 units

Computer-aided design of a chemical product. Course involves design of molecular structure, microstructure, or devices/processes that effect chemical change. This is a project-based course, for which an extensive report must be submitted.

Prerequisite: 06-421

06-464 Chemical Engineering Process Control

Spring: 9 units

This course presents basic concepts of process dynamics and feedback control. Included are selection of measurements and manipulated variables, definition of transfer functions, creation of block diagrams and closed loop configurations. The course also covers concepts of open loop and closed loop stability, and tuning of PID controllers.

Prerequisite: 06-325

06-466 Experimental Polymer Science

Spring: 9 units

Macromolecular behavior in bulk and in solution will be explored in experiments on tensile strength, elasticity, swelling of networks, solution viscosity, melt flow, and polymerization reactions. Particular reference will be made to aspects affecting production and fabrication of polymeric materials.

Prerequisites: 09-221 and (06-609 or 09-509)

06-606 Computational Methods for Large Scale Process Design & Analysis

Spring: 9 units

This course deals with the underlying computer-aided design techniques for steady-state and dynamic simulation, numerical solution and decomposition strategies for large systems of sparse nonlinear algebraic equations, stiff ordinary differential equations, strategies for mixed algebraic/differential systems and computer architectures for flowsheeting systems.

Prerequisites: 06-361 and 06-262

Course Website: <http://numero.cheme.cmu.edu/course/06606.html>**06-607 Physical Chemistry of Colloids and Surfaces**

All Semesters: 9 units

Thermodynamics of surfaces; adsorption at gas, liquid, and solid interfaces; capillarity; wetting, spreading, lubrication and adhesion; properties of monolayers and thin films; preparation and characterization of colloids; colloidal stability, flocculation kinetics, micelles, electrokinetic phenomena and emulsions.

06-609 Physical Chemistry of Macromolecules

Fall: 9 units

This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to molecular structure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. Students not having the prerequisite listed may seek permission of the instructor.

06-610 Rheology and Structure of Complex Fluids

Fall: 9 units

This course will cover the basic concepts of rheology and mechanical behavior of fluid systems. Both the experimental and theoretical aspects of rheology will be discussed. The basic forces influencing complex fluid rheology and rheology will be outlined and discussed; including excluded volume, van der Waals, electrostatic and other interactions. Methods of characterizing structure will be covered including scattering techniques, optical polarimetry and microscopy. Examples will focus on several types of complex fluids including polymer solutions and melts, gelling systems, suspensions and self-assembling fluids.

06-612 Formulation Engineering

Intermittent: 12 units

Students will learn the scientific and design principles needed for careers in complex fluid formulation-based industries such as consumer products, pharmaceuticals, paints, agrochemicals or lubricants. The essential science and engineering principles of colloids, surfactants, interfaces and polymer solutions will be introduced. Students will learn to use these principles in combination with experimental measurements and statistical design of experiments tools to design effective liquid product formulations within specified economic, material and even aesthetic constraints. The lecture portion of the course is complemented by weekly lab sessions where student teams will design, prepare, test and improve their own formulations for a commercial complex fluid product, such as a detergent or an ink, that meets performance goals within specified constraints.

06-614 Special Topics: Atmospheric Nanoparticles and Climate

Fall and Spring: 12 units

This course will examine the physicochemical properties of atmospheric nanoparticles and the chemical processes that form these particles. We will also cover basic techniques for characterizing atmospheric nanoparticles using fundamentals of aerosol physics and chemistry. The last portion of the course will explore how atmospheric nanoparticles affect the Earth's radiative budget and ultimately climate. Students will apply their atmospheric nanoparticle knowledge to determine the feasibility and effectiveness of various atmospheric geoengineering techniques proposed in literature. Though this course targets atmospheric nanoparticles, it is also broadly applicable to anyone interested applications of aerosolized nanoparticles. Prerequisites: undergraduate chemistry and physics

06-623 Mathematical Modeling of Chemical Engineering Processes

Fall: 12 units

Numerical approaches to solving problems relevant to chemical engineering applications. In this course, advanced mathematical topics relevant to chemical engineering will be used to solve complex problems. Topics include linear algebra, nonlinear equation solving, initial value and boundary value problems for solution of differential equations, numerical optimization, probability and stochastic methods. Significant focus will be placed on numerical rather than analytical solution to problems. Primary Software Package(s): Mathematical programming environment.

06-625 Chemical and Reactive Systems

Fall: 12 units

In this course process simulation software will be used to develop models of chemical and reactive systems. The models will be used to predict the performance of the system, as well as to probe how process modifications, e.g. process conditions, reactor types or sequences, etc? affect system performance. The effects of the underlying thermodynamic and kinetic databases of chemical properties on the performance predictions will be explored. Methods to incorporate new thermodynamic and kinetic data into chemical and reactive system simulations will be examined. Thermochemical and kinetic data for reactions will be estimated for use in process simulation software. Primary Software Package(s): Molecular modeling and process simulation software.

06-634 Drug Delivery Systems

Fall and Spring: 9 units

The body is remarkable in its ability to sequester and clear foreign entities - whether they be "bad" (e.g. pathogens) or "good" (e.g. therapeutic drugs). This course will explore the design principles being used to engineer modern drug delivery systems capable of overcoming the body's innate defenses to achieve therapeutic effect. Specifically, we will study the chemistry, formulation, and mechanisms of systems designed to deliver nucleic acids, chemotherapeutics, and proteins across a variety of physiological barriers. Scientific communication plays a prominent role in the course, and students will have several opportunities to strengthen their communication skills through journal club presentations, proposal writing and constructive feedback. This is a graduate level course that is also open to undergraduate seniors.

06-663 Analysis and Modeling of Transport Phenomena

Spring: 12 units

Students will learn the basic differential equations and boundary conditions governing momentum, heat, and mass transfer. Students will learn how to think about these equations in dimensionless terms and will apply them to model physical and chemical processes. The primary mode for solving them will be numerical. Analytical results for classical problems of high symmetry also will be presented to serve as a basis for comparison and validation. Software: A finite element and computational transport tool.

06-665 Process Systems Modeling

Spring: 12 units

Simulation and optimization of complex flowsheets, synthesis of separation systems, planning and enterprise-wide optimization, process control and molecular design. Primary Software Package(s): Process Simulation software. Target Audience: first year masters students in chemical engineering Prerequisite skills: analytical and mathematical skills typical of an undergraduate engineering degree or technical degree.

06-679 Introduction to Meteorology

Fall and Spring: 12 units

Provide you with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the class you will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). You will understand what makes weather happen and you will understand weather maps and charts. You will be able to critically watch the nightly weather forecast and you will be able to access available meteorological databases to make informed predictions of your own. Finally, you will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if you are pursuing those topics more deeply.

06-681 Special Topics: Data Science and Machine Learning in Chemical Engineering

Spring: 6 units

This class will examine topics related to data science and machine learning in chemical engineering. This may include topics in data visualization and modeling, differentiable programming, and the use of data and models to design experiments. The course will emphasize computational implementations of these topics using Python, with applications in chemical engineering. Students will need to be comfortable with scientific programming using Python. Students who have take 06-623 and/or 06-625 should have the skills needed in this class.

06-682 ST: Data Science & Machine Learning in Chemical Engineering: Scientific Software

Spring: 6 units

Creating scientific research software This class will introduce topics in software engineering for scientific research. We will cover using a shell for running command line programs, automation tools for building software, version control systems, and how to create and distribute software packages. Prior programming experience with Python is highly recommended. The course will include a final project in developing a software package that is to be used in scientific research.

06-685 Special Topics: Bioseparations and Spectroscopy

Spring: 12 units

This course gives an introduction to key principles of bioseparations and process analytical technologies relevant to the manufacture of biopharmaceuticals. Transport modeling principles are applied to sedimentation/centrifugation, flocculation, and filtration of antibodies and plasmid DNA from raw cell culture. Polishing methods such as Protein A chromatography and size-exclusion chromatography are a particular focus. Chemical means to graft affinity ligands to commercial media are discussed along with in-line spectroscopic techniques. A molecular-level basis of light absorbance and fluorescence is established and the selection and conjugation of fluorophores to biomolecules of interest is presented. Means to assess the state of antibody aggregation and the proper folding of protein-based therapeutics are covered in the context of spectroscopic identification. Finally, the course will provide an overview of the diverse metrics needed for analysis of biomacromolecules as well as the variety of techniques used to analyze quality of produced materials by comparing cost, speed, accuracy and precision.

06-702 Advanced Reaction Kinetics

Spring: 12 units

Advanced application of engineering and scientific principles to the study of complex chemical reaction systems. Catalytic and noncatalytic reactions in homogeneous and heterogeneous systems, fast reaction techniques, and isothermal and non-isothermal reaction design.

06-705 Advanced Chemical Engineering Thermodynamics

Fall: 12 units

Advanced application of the general thermodynamic method to chemical engineering problems. Second law consequences, estimation and correlation of thermodynamic properties, and chemical and phase equilibria.

06-713 Mathematical Techniques in Chemical Engineering

Fall: 12 units

Selection, construction, solution, and interpretation of mathematical models applicable to the study of chemical engineering problems. Mathematical topics emphasized include divergence, curl and gradient operators, vector field theory, the solution of ordinary and partial differential equations by infinite series, separation of variables, Green's functions, regular and singular perturbations, and boundary-layer techniques.

06-714 Surfaces and Adsorption

Fall and Spring: 12 units

A survey of solid surfaces and gas-solid interactions. Topics include the structure and electronic properties of metal surfaces, the kinetics and thermodynamics of adsorption and desorption processes, and concepts in heterogeneous catalysis. The course emphasizes the application of recent experimental techniques in studying these problems.

06-722 Bioprocess Design

Fall and Spring: 12 units

This course is designed to link concepts of cell culture, bioseparations, formulation, and delivery together for the commercial production and use of biologically-based pharmaceuticals; products considered include proteins, nucleic acids, and fermentation-derived fine chemicals. Associated regulatory issues and biotech industry case studies are also included. A fair knowledge of cell culture and fermentation operations is assumed.

Department of Civil and Environmental Engineering

Burcu Akinci, Head
Location: Porter Hall 119-D
www.cmu.edu/cee (<http://www.cmu.edu/cee/>)

The role of civil and environmental engineers, in the broadest sense, is to apply science and technology to develop sustainable solutions to meet society's needs. Civil engineers plan, design, construct, operate, and maintain infrastructure used daily by the public and industry, such as buildings, transportation networks, water systems, and energy distribution systems. Civil and environmental engineers are at the forefront of technological developments to address the biggest societal challenges. They work to protect public health and the environment. Today's civil and environmental engineers are also called upon by government and industry to provide leadership on complex technical and societal issues such as demands for infrastructure improvement, remediation of former industrial sites for reuse, renewable energy, climate change adaptation, provision of safe drinking water, smart transportation systems, and sustainable development.

The department offers undergraduate degree programs leading to a B.S. in Civil Engineering or a B.S. in Environmental Engineering.

The B.S. in Civil Engineering provides a broad exposure to the field and its sub-disciplines, including environmental engineering. The B.S. in Environmental Engineering offers the opportunity to focus primarily on environmental sciences and engineering. The two programs share a number of common courses.

The Civil Engineering and Environmental Engineering curricula emphasize fundamental understanding of the behavior of constructed facilities and the natural environment and the design of infrastructure through the application of the physical sciences, chemistry, biology, mathematics, and computing. In addition to providing a solid technical foundation, the programs emphasize the development of professional skills. We incorporate design and team experiences throughout the curriculum, and provide hands-on experience in laboratory and project courses. Students also have multiple opportunities to practice and improve their communication skills through reports, presentations, and team activities.

The curricula allow many opportunities for students to pursue areas of personal interest. Students may pursue a minor in one of the designated minor programs offered in the College of Engineering or elsewhere in the university or an additional major. Students may also choose to concentrate in a specialty area in civil or environmental engineering. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Faculty mentors and the Director of Undergraduate Programs are available to discuss students' educational goals and help define a path to reach them.

The Department of Civil and Environmental Engineering offers a wide spectrum of opportunities for entry into the engineering profession, for graduate education in engineering, or entry into various other graduate and professional fields, including business, law, and medicine. Our curricula emphasize the development of scientific inquiry in the context of applications in civil and environmental engineering. For B.S. graduates who wish to enter the engineering profession directly in such specialties as structural engineering, construction engineering, computer-aided engineering, or environmental engineering, this approach to teaching allows application of the most advanced technological developments. Those who wish to pursue graduate study are prepared to engage in research on the highest level, either in traditional specialties or in emerging fields such as smart infrastructure, climate change adaptation, and micromechanics.

Program Educational Objectives

The Program Educational Objectives are broad statements that describe what graduates are expected to attain within a few years of graduation. The objectives of the Bachelor of Science in Civil Engineering program are to develop graduates who embody the following definitions:

- Graduates distinguish themselves within their organizations as individuals able to provide sustainable solutions to a wide range of conventional, cutting-edge, and emerging professional challenges related to one or more of the areas of the built, natural, and information environments.

- Graduates are innovative, proactive, and adaptive professionals, highly engaged in their professional communities; graduates are prepared to take on leadership positions within their organizations and communities.
- Graduates are able to contribute and collaborate on developing sustainable solutions to local and global problems; graduates are able to cross geographic, cultural, and traditional discipline boundaries in developing solutions; graduates are able to develop just and equitable solutions.

The Bachelor of Science in Civil Engineering program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

By the end of the B.S. program, students should have achieved the following student outcomes:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

The curriculum has been designed, and is periodically evaluated and refined, to provide students instruction and experiences that lead to the development of these abilities and skills.

The Bachelor of Science in Environmental Engineering will complete its first cycle of graduating students in May 2024 and will be formally evaluated by ABET later that year. The program was designed in accordance with ABET general and program criteria. Accreditation would be applicable retroactively to the May 2024 graduates.

Curriculum: B.S. Civil Engineering

Minimum units required for B.S. in Civil Engineering 384

Students entering the College of Engineering declare a major near the end of the first year. First-year students take two introductory engineering courses as well as some restricted technical electives within the common foundation specified for first-year engineering students. By the end of the sophomore year, a Civil Engineering major is expected to have completed the Restricted Technical Electives in the following list and 12-100 Exploring CEE: Infrastructure and Environment in a Changing World.

| Restricted Technical Electives | Units |
|--|-------|
| 09-101 Introduction to Experimental Chemistry | 3 |
| 09-105 Introduction to Modern Chemistry I | 10 |
| or 09-111 Nanolegos: Chemical Building Blocks | |
| 15-110 Principles of Computing | 10 |
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| 21-259 Calculus in Three Dimensions | 9 |
| or 21-254 Linear Algebra and Vector Calculus for Engineers | |
| 21-260 Differential Equations | 9 |
| 33-141 Physics I for Engineering Students | 12 |
| 33-142 Physics II for Engineering and Physics Students | 12 |

Notes on Math Requirements

1. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

Sample Curriculum

This section shows the recommended four-year program of study for the BS in Civil Engineering following a typical path. The curriculum for transfer students, students with advanced placement credit, and students planning to study abroad will not follow the same path. Students need to consult the department for appropriate advising and formulation of a plan to complete the degree within eight semesters.

First Year

| | | Units |
|--------|---|-----------|
| Fall | | |
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 33-141 | Physics I for Engineering Students | 12 |
| 99-10x | Computing @ Carnegie Mellon | 3 |
| xx-xxx | General Education Course | 9 |
| | | 46 |
| Spring | | |
| xx-xxx | Introduction to Engineering (other than CEE) | 12 |
| 21-122 | Integration and Approximation | 10 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-101 | Introduction to Experimental Chemistry | 3 |
| xx-xxx | General Education Course | 9 |
| | | 46 |

Sophomore Year

| | | Units |
|-----------|--|-----------|
| Fall | | |
| 12-200 | CEE Challenges: Design in a Changing World | 9 |
| 12-212 | Statics | 9 |
| 12-233 | CEE Infrastructure Systems in Action | 2 |
| 21-259 | Calculus in Three Dimensions | 9 |
| or 21-254 | Linear Algebra and Vector Calculus for Engineers | |
| 15-110 | Principles of Computing | 10 |
| xx-xxx | General Education Course | 9 |
| 39-210 | Experiential Learning I | 0 |
| | | 48 |
| Spring | | |
| 12-231 | Solid Mechanics | 9 |
| 12-234 | Sensing and Data Acquisition for Engineering Systems | 4 |
| 12-271 | Computation and Data Science for Civil & Environmental Engineering | 9 |
| 21-260 | Differential Equations | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| xx-xxx | General Education Course | 9 |
| 39-220 | Experiential Learning II | 0 |
| | | 49 |

Junior Year

| | | Units |
|-----------|---|-------|
| Fall | | |
| 12-301 | CEE Projects: Integrating the Built, Natural and Information Environments | 9 |
| 12-335 | Soil Mechanics | 9 |
| 12-355 | Fluid Mechanics | 9 |
| 12-356 | Fluid Mechanics Lab | 2 |
| 09-111 | Nanolegos: Chemical Building Blocks | 9 |
| or 09-105 | Introduction to Modern Chemistry I | |
| xx-xxx | Elective 1 | 9 |

| | | |
|--------|--|-----------|
| 39-310 | Experiential Learning III | 0 |
| | | 47 |
| Spring | | |
| 12-351 | Environmental Engineering | 9 |
| 27-357 | Introduction to Materials Selection | 6 |
| 12-371 | Advanced Computing and Problem Solving in Civil and Environmental Engineering | 9 |
| 12-333 | Experimental & Sensing Systems Design and Computation for Infrastructure Systems | 4 |
| xx-xxx | Elective 2 | 9 |
| xx-xxx | General Education Course | 9 |
| | | 46 |

Senior Year

| | | Units |
|--------|---|-----------|
| Fall | | |
| 12-401 | CEE Design: Imagine, Build, Test | 12 |
| 12-411 | Project Management for Engineering and Construction | 9 |
| xx-xxx | Elective 3 | 9 |
| xx-xxx | Elective 4 | 9 |
| xx-xxx | General Education Course | 9 |
| | | 48 |
| Spring | | |
| xx-xxx | General Education Course | 9 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | Elective 5 | 9 |
| xx-xxx | Elective 6 | 9 |
| xx-xxx | Elective 7 | 9 |
| xx-xxx | Elective 8 | 9 |
| | | 54 |

Notes on Electives

1. One elective must be in the basic sciences, from the following list:

| | | |
|--------|-----------------------------------|---|
| 03-121 | Modern Biology | 9 |
| 12-201 | Geology | 9 |
| 12-353 | Environmental Biology and Ecology | 9 |

 Substitutions may be made only with the approval of the Department Head.
2. One elective course is restricted to a 600-level or 700-level Civil Engineering course of at least 9 units, except 12-648 and 12-690. The combination of 12-644 and 12-645 may also be used, but no other combination is allowed.
3. **Students are encouraged to take multiple 12-6xx and 12-7xx courses to provide them with specific civil engineering domain depth in their field(s) of interest.**

Curriculum: B.S. Environmental Engineering

Minimum units required for B.S. in Environmental Engineering 384

Students entering the College of Engineering declare a major near the end of the first year. First-year students take two introductory engineering courses as well as some restricted technical electives within the common foundation specified for first-year engineering students. By the end of the sophomore year, an Environmental Engineering major is expected to have completed the Restricted Technical Electives in the following list and 12-100 Exploring CEE: Infrastructure and Environment in a Changing World.

| | | |
|-----------|--|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-111 | Nanolegos: Chemical Building Blocks | |
| 15-110 | Principles of Computing | 10 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 33-141 | Physics I for Engineering Students | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |

Notes on Math Requirements

1. All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a pre-requisite for the next higher level required mathematics (21-xxx) course.

SAMPLE CURRICULUM

This section shows the recommended four-year program of study for the BS in Environmental Engineering following a typical path. The curriculum for transfer students, students with advanced placement credit, and students planning to study abroad will not follow the same path. Students need to consult the department for appropriate advising and formulation of a plan to complete the degree within eight semesters.

First Year

| Fall | | Units |
|--------|---|-----------|
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 33-141 | Physics I for Engineering Students | 12 |
| 99-10x | Computing @ Carnegie Mellon | 3 |
| xx-xxx | General Education Course | 9 |
| | | 46 |

| Spring | | Units |
|-----------|---|-----------|
| xx-xxx | Introduction to Engineering (other than CEE) | 12 |
| 21-122 | Integration and Approximation | 10 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-111 | Nanolegos: Chemical Building Blocks | |
| 09-101 | Introduction to Experimental Chemistry | 3 |
| | | 47 |

Sophomore Year

| Fall | | Units |
|--------|--|-----------|
| 12-200 | CEE Challenges: Design in a Changing World | 9 |
| 12-221 | Environmental Chemistry and Thermodynamics | 9 |
| 12-222 | Environmental Chemistry Laboratory | 3 |
| 15-110 | Principles of Computing | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 39-210 | Experiential Learning I | 0 |
| xx-xxx | General Education Course | 9 |
| | | 51 |

| Spring | | Units |
|--------|--|-----------|
| 12-271 | Computation and Data Science for Civil & Environmental Engineering | 9 |
| 12-351 | Environmental Engineering | 9 |
| 12-352 | Environmental Engineering Lab | 3 |
| 21-260 | Differential Equations | 9 |
| 39-220 | Experiential Learning II | 0 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | Elective 1 | 9 |
| | | 48 |

Junior Year

| Fall | | Units |
|--------|--|-----------|
| 12-301 | CEE Projects: Integrating the Built, Natural and Information Environments | 9 |
| 12-355 | Fluid Mechanics | 9 |
| 12-356 | Fluid Mechanics Lab <small>Starting in Fall 2022, 12-356 will be 2 units</small> | 2 |
| 03-121 | Modern Biology | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 39-310 | Experiential Learning III | 0 |
| xx-xxx | General Education Course | 9 |
| | | 47 |

| Spring | | Units |
|--------|---|-----------|
| 12-353 | Environmental Biology and Ecology | 9 |
| 12-371 | Advanced Computing and Problem Solving in Civil and Environmental Engineering | 9 |
| 12-201 | Geology | 9 |
| xx-xxx | Elective 2 | 6 |
| xx-xxx | Elective 3 | 9 |
| xx-xxx | General Education Course | 9 |
| | | 51 |

Senior Year

| Fall | | Units |
|--------|---|-----------|
| 12-401 | CEE Design: Imagine, Build, Test | 12 |
| 12-411 | Project Management for Engineering and Construction | 9 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | General Education Course | 9 |
| | | 48 |

| Spring | | Units |
|--------|--|-----------|
| 12-451 | Advanced Environmental Engineering | 9 |
| 12-471 | Applied Data Analytics for Civil and Environmental Systems | 9 |
| xx-xxx | Upper Level Environmental Engineering Elective | 9 |
| xx-xxx | Elective 4 | 9 |
| xx-xxx | Elective 5 | 9 |
| | | 45 |

Notes on Electives

1. Students are encouraged to take multiple upper level courses to provide them with specific environmental engineering domain depth in their field(s) of interest.

Specialty Areas in Civil Engineering

Students may select a set of civil engineering and other electives in the junior and senior years that enable them to concentrate in a specialty area, if they so desire. Some examples for grouping electives into specialty areas, together with representative course selections, are indicated below. Students can define other specialty area concentrations; discussion with a faculty mentor is encouraged. Specialty areas are not noted on the official transcript.

STRUCTURAL ENGINEERING

| | Units |
|--|-------|
| 12-201 Geology | 9 |
| 12-631 Structural Design | 12 |
| 12-635 Structural Analysis | 12 |
| 12-636 Geotechnical Engineering | 9 |
| 21-241 Matrices and Linear Transformations | 10 |
| 24-311 Numerical Methods | 12 |
| 24-351 Dynamics | 10 |

Computing in Civil Engineering

| | Units |
|----------------|-------|
| 12-600 AutoCAD | 3 |

| | | |
|--------|---|----|
| 12-623 | Molecular Simulation of Materials | 12 |
| 12-645 | Smart Cities: Growth and Intelligent Transportation Systems | 6 |
| 12-659 | Special Topics: Matlab | 6 |
| 24-451 | Feedback Control Systems | 12 |
| 24-650 | Applied Finite Element Analysis | 12 |
| 24-658 | Image-Based Computational Modeling and Analysis | 12 |

engineering and society

| | Units | |
|--------|---|---|
| 12-645 | Smart Cities: Growth and Intelligent Transportation Systems | 6 |
| 12-657 | Water Resource Systems Engineering | 9 |
| 24-291 | Environmental Systems on a Changing Planet | 9 |
| 48-371 | City & Suburb: Housing in America after 1850 | 9 |
| 79-303 | Pittsburgh and the Transformation of Modern Urban America | 6 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |

Construction Management

| | Units | |
|--------|-------------------------------------|----|
| 12-600 | AutoCAD | 3 |
| 12-631 | Structural Design | 12 |
| 12-635 | Structural Analysis | 12 |
| 12-636 | Geotechnical Engineering | 9 |
| 48-380 | Real Estate for Architects | 6 |
| 70-311 | Organizational Behavior | 9 |
| 70-321 | Negotiation and Conflict Resolution | 9 |

NEXT-GENERATION BUILDING AND CONSTRUCTION

| | Units | |
|--------|--|----|
| 12-631 | Structural Design | 12 |
| 39-245 | Rapid Prototype Design | 9 |
| 48-530 | Human-Machine Virtuosity | 12 |
| 48-555 | Introduction to Architectural Robotics | 9 |

SMART CITIES

| | Units | |
|--------|---|----|
| 12-600 | AutoCAD | 3 |
| 12-612 | Intro to Sustainable Engineering | 9 |
| 12-631 | Structural Design | 12 |
| 12-635 | Structural Analysis | 12 |
| 12-636 | Geotechnical Engineering | 9 |
| 12-644 | Special Topics: Intro to Transportation Systems Analysis | 6 |
| 12-645 | Smart Cities: Growth and Intelligent Transportation Systems | 6 |
| 24-643 | Energy Storage Materials and Systems | 12 |

SMART BUILDINGS

| | | |
|--------|---|----|
| 12-600 | AutoCAD | 3 |
| 12-631 | Structural Design | 12 |
| 12-635 | Structural Analysis | 12 |
| 48-116 | Introduction to Building Performance | 9 |
| 48-315 | Environment I: Climate & Energy in Architecture | 9 |
| 48-432 | Environment II: Design Integration of Active Building Systems | 9 |

MATERIALS

| | Units | |
|--------|--------------------------------------|----|
| 12-623 | Molecular Simulation of Materials | 12 |
| 24-643 | Energy Storage Materials and Systems | 12 |
| 27-201 | Structure of Materials | 9 |
| 27-202 | Defects in Materials | 9 |
| 27-215 | Thermodynamics of Materials | 12 |
| 27-301 | Microstructure and Properties I | 9 |

| | | |
|--------|--------------------------------------|---|
| 27-406 | Sustainable Materials | 9 |
| 27-503 | Additive Manufacturing and Materials | 9 |

Specialty Areas in Environmental Engineering

ENVIRONMENTAL ENGINEERING - WATER QUALITY

| | | Units |
|--------|--|-------|
| 09-106 | Modern Chemistry II | 10 |
| 09-510 | Chemistry and Sustainability | 9 |
| 12-612 | Intro to Sustainable Engineering | 9 |
| 12-629 | Environmental Microbiology for Engineers | 9 |
| 12-657 | Water Resource Systems Engineering | 9 |

ENGINEERING AND SOCIETY

| | | Units |
|--------|---|-------|
| 12-645 | Smart Cities: Growth and Intelligent Transportation Systems | 6 |
| 12-657 | Water Resource Systems Engineering | 9 |
| 24-291 | Environmental Systems on a Changing Planet | 9 |
| 48-371 | City & Suburb: Housing in America after 1850 | 9 |
| 79-303 | Pittsburgh and the Transformation of Modern Urban America | 6 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |

ENVIRONMENTAL ENGINEERING - ENERGY

| | | Units |
|--------|--|-------|
| 09-106 | Modern Chemistry II | 10 |
| 12-612 | Intro to Sustainable Engineering | 9 |
| 24-424 | Energy and the Environment | 9 |
| 24-292 | Renewable Energy Engineering | 9 |
| 24-628 | Energy Transport and Conversion at the Nanoscale | 12 |

ENVIRONMENTAL ENGINEERING - AIR QUALITY

| | | Units |
|--------|--------------------------------------|-------|
| 09-106 | Modern Chemistry II | 10 |
| 09-510 | Chemistry and Sustainability | 9 |
| 12-612 | Intro to Sustainable Engineering | 9 |
| 12-651 | Air Quality Engineering | 9 |
| 24-425 | Combustion and Air Pollution Control | 9 |

Additional Majors and Minors

Civil Engineering and Environmental Engineering students may pursue additional majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has designated minors to promote flexibility and diversity among engineering students. Many Civil Engineering and Environmental Engineering undergraduates pursue designated minors in areas such as Architecture, Environmental and Sustainability Studies, or Global Engineering.

Internships and Co-Operative Education Program

Students in Civil Engineering and Environmental Engineering are encouraged to undertake professional internships during summer breaks. In addition, a cooperative internship program is possible for either Jan-Aug or May-Dec in the junior year. Students undertaking these 8-month professional internships would ordinarily graduate after an additional semester of study.

Integrated B.S./M.S. Program

Interested undergraduates may plan a course of study that leads to either the B.S. in Civil Engineering or the B.S. in Environmental Engineering as well as the M.S. in Civil and Environmental Engineering. This course of study will

ordinarily require ten semesters, although advanced placement or other study may reduce this time. In the ninth semester of study, students must register in graduate status. Interested students should consult the Director of Undergraduate Programs for information about admission to the M.S. program.

Faculty

AMIT ACHARYA, Professor of Civil and Environmental Engineering – Ph.D., University of Illinois at Urbana - Champaign; Carnegie Mellon, 2000-

PETER ADAMS, Thomas Lord Professor of Engineering, Civil and Environmental Engineering and Engineering and Public Policy; Department Head of Engineering and Public Policy – Ph.D., California Institute of Technology; Carnegie Mellon, 2001-

BURCU AKINCI, Department Head and Paul P. Christiano Professor of Civil and Environmental Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000-

MARIO BERGES, Professor of Civil and Environmental Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010-

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Department of Civil and Environmental Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

12-100 Exploring CEE: Infrastructure and Environment in a Changing World

Fall and Spring: 12 units

Civil and Environmental Engineers (CEEs) engage in the planning, design, construction, operation, retrofit, demolition, and reuse of large-scale infrastructure that forms the backbone of all societies and economies. CEEs work at the dynamic interface of the built environment, information environment, and natural environment. Therefore, societal domains that require CEE expertise include smart cities and construction, sustainable energy and buildings, connected and automated transportation systems, resilient infrastructure, climate change mitigation and adaptation, and water management. Students will explore how sensing, data science, environmental science, life cycle systems and economic analysis, and infrastructure design are integrated to create a built environment that meets the needs of smart and connected communities while enhancing sustainability. Students work on team-based design-build projects that introduce principles from environmental, structural, construction engineering, and project management. Students learn technical skills as well as methods for management and design considerations that include uncertainty, economics, and ethics, for modern and future infrastructure.

12-200 CEE Challenges: Design in a Changing World

Fall: 9 units

Building upon design themes introduced in 12-100, in this course, students will be challenged to solve more complex problems related to conventional, cutting-edge, and emerging issues in Civil and Environmental Engineering and one or more of the areas of the built, natural, and information environments, such as smart cities. Students will gain an understanding of the effects of uncertainty, such as changing climate conditions. Through several team projects, students will explore the impact and management of tradeoffs, like constructability, sustainability, cost, and maintenance on design. They will learn to apply mathematics and science, advanced technologies, and computing to solve open-ended problems. Students will learn communication, project management, and design skills and practice the design process, from problem definition to constructed work.

Prerequisite: 12-100

12-201 Geology

Fall and Spring: 9 units

Introduction to physical geology; common rocks and rock-forming minerals and their chemical compositions/structure, physical properties, origins, and uses; geologic processes: surface and ground-water flow, volcanism, mountain-building, tectonics, glaciation, sedimentation, seismicity, and atmospheric and oceanic circulation.

12-212 Statics

Fall: 9 units

Introduction to vector mechanics; equivalent systems of forces; equilibrium of rigid bodies; free body diagram; distributed forces, hydrostatic forces, effective forces, centroids; applications to simple statically determinate trusses, beams, frames, cables and other physical systems; friction.

12-215 Introduction to Professional Writing in CEE

Fall: 9 units

The objective of the course is to prepare students for writing technical reports and essays assigned in CEE courses and laboratories, writing professional letters and reports for internships and professional positions, preparing documents in a team setting, delivering individual and team oral presentations, and transforming information for several types of audiences (scientific accommodation). The course focuses on document purpose, organization and style; basic editing techniques; scientific accommodation; plagiarism and proper paraphrasing and summarizing; evaluating, citing and referencing sources; team communication strategies; oral presentations; and proper use of tables, graphics, and other visual aids in documents and presentations. Course activities include in-class exercises, peer workshops, and homework assignments to illustrate examples of good and poor communication and to practice technical communication skills. Concurrent with lectures and class activities, students draft and revise individual and team technical reports and will give individual and team oral presentations.

12-216 Research Skills and Topics in Civil and Environmental Engineering

Spring: 3 units

Civil Engineering undergraduates will learn and practice research skills relevant to both academic research and engineering practice. Exposure to a breadth of cutting-edge Civil Engineering research topics and projects will be achieved through expert presentations and practical exercises.

Prerequisite: 12-100

12-221 Environmental Chemistry and Thermodynamics

Fall: 9 units

Environmental chemistry is foundational to the understanding of processes in natural and engineered systems. This course introduces environmental chemistry principles within the context of air and water systems. It focuses on the use of stoichiometry, thermodynamics, equilibrium, and kinetics to understand processes governing chemical and biological behaviors in natural and engineered systems. Topics in water include acid-base chemistry, the carbonate system, buffering, oxidation and reduction, mineral dissolution/precipitation, metal complexation, adsorption, and partitioning. Topics in air and climate to be discussed include atmospheric chemistry, air quality, combustion, aerosols, and climate science.

Prerequisites: 09-105 or 09-111

12-222 Environmental Chemistry Laboratory

Fall: 3 units

Students learn to conduct lab and field experiments relevant to environmental engineering and the understanding of natural and engineered systems. Exercises involve the collection and analysis of data from major domains of the environment (air, water, soil, sediments). Students learn to use state-of-the-art environmental analytical techniques. Students develop collaborative skills through team-based laboratory exercises and practice skills in written communication of laboratory results.

12-231 Solid Mechanics

Spring: 9 units

Understanding and calculating the deformation and eventual failure of solids is fundamental to the design of structures and materials for civil engineering applications ranging from structural analysis and design of buildings and bridges to the design of novel materials and structures optimized for specific functionality. This course provides students with an introduction to fundamental concepts and methods in solid mechanics. Topics covered include stress, strain, mechanical properties of materials, and geometric compatibility; response under axial loads, torsion, bending, transverse shear, and combined loadings; stress transformations and Mohr's circles, deflections of beams and shafts, and buckling of columns. Students will develop problem solving skills and apply these concepts to analyze deformable bodies.

Prerequisite: 12-212

12-232 Solid Mechanics Lab

Spring: 3 units

The deformation of solids due to external forces is important in many civil engineering applications, including structural engineering, pavement engineering, and others. This lab course allows students to see how solids deform and understand the connection between the theory they learn in the classroom and the experiments they conduct. Students will learn the basics of conducting experiments, analyzing the resulting data, drawing insights on the observed behavior from the data analysis, and preparing lab reports to document the observed behavior. Students will learn about laboratory procedures and analog and digital measurement.

Prerequisite: 12-212

12-233 CEE Infrastructure Systems in Action

Fall: 2 units

Civil and environmental engineering infrastructure is all around us. CEE infrastructure is integral to society's day-to-day operations, providing, for example, shelter, transportation, and clean drinking water. In this course, students will get a first-hand experience of civil and environmental engineering in action all around us. The course is comprised of lab sessions during which students will learn about and investigate infrastructure and phenomena in the built and natural environments on or near campus. Student coursework includes short assignments and reflections related to the lab experience.

Prerequisite: 12-100

12-234 Sensing and Data Acquisition for Engineering Systems

Spring: 4 units

Collecting and analyzing massive amounts of data is integral to understanding and managing the complexities of our infrastructure systems. Civil and environmental engineers need to select tools and to collect data to gain an understanding of the problems they are trying to solve. In this course, students will learn how to choose and use a range of measuring tools from simple hand tools to advanced sensors to collect data in laboratory-based and system-level studies, followed by data acquisition and processing. Experiment subjects will span the breadth of the fields including, for example, structural, geotechnical, environmental, and transportation engineering. The sensors and data will be used to assess not only an individual infrastructure component, but also infrastructure systems and networks. Students will complete planning activities for each of the experiments, conduct experiments, and acquire the resulting data from sensors and other measurements. Results and analysis will be submitted as part of a report or post-laboratory assignment.

Prerequisite: 12-212

12-271 Computation and Data Science for Civil & Environmental Engineering

Spring: 9 units

Computational science and computer applications play an important role in modern engineering practice and research. This course provides students with an introduction to the fundamentals of computation and data science using both deterministic and stochastic techniques. Topics include numerical methods for approximation, differentiation, integration, Monte Carlo simulation, quantifying error and uncertainty, regression, solving linear systems of equations and ordinary differential equations, root finding, and optimization; the use of several computing paradigms (numerical, symbolic, and spreadsheet) for enhancing engineering workflows with modeling and data, with an emphasis on identifying the appropriate tool for various engineering problems; the importance of and approaches for effective visual presentation of data; and the future of computer-based methods in engineering. Mathematical concepts from calculus, probability, and linear algebra are introduced as needed. Through application of these principles, students will develop the computational reasoning skills that are required to design and deploy computer-based solutions for a variety of problems in civil and environmental engineering.

Prerequisites: 21-120 Min. grade C and 33-141 and (15-112 or 15-110) and 21-122 Min. grade C

12-301 CEE Projects: Integrating the Built, Natural and Information Environments

Fall: 9 units

Civil and environmental engineers work at the interface of multiple disciplines, understanding and applying principles to evaluate and create. This course extends design skills from 12-100 and 12-200 to hands-on experiences with more integrated, interdisciplinary problem solving. Students explore the roles of diverse stakeholders, community engagement, and sustainability goals in CEE projects. Students integrate construction/structures, sensing, and sustainability through team-based projects, and apply communication, computation, and project management skills. Students develop an understanding of the professional, ethical, social, and economic aspects of engineering projects. The course combines formal instruction, field trips, teamwork, role-playing, and engagement with practicing experts involved with CEE projects.

Prerequisites: 12-200 and 12-271

12-333 Experimental & Sensing Systems Design and Computation for Infrastructure Systems

Spring: 4 units

Civil and environmental engineers must decide what information they need to collect, how to collect it, how to analyze the data and how to use that data to develop solutions for a changing world. Data are often incorporated into computational models to gain further insight and understanding of the problem and potential solutions. In this course, students will learn and develop different approaches to solve problems like field testing, laboratory experimentation, computer simulation, and data analytics. Students will design their own testing protocols and develop computer models to simulate situations that are difficult or expensive to sense in the real-world. Pre- and post-laboratory assignments or reports will be completed to document plans and to present an analysis of results.

Prerequisite: 12-356

12-335 Soil Mechanics

Fall: 9 units

Understanding the behavior of soils is essential for many applications within civil and environmental engineering from construction safety and structural integrity of buildings, to foundations, levees, groundwater remediation, landfill design, and erosion control. This course provides students with an introduction to fundamental concepts and methods in soil mechanics and geotechnical engineering. Topics covered in the course include physical, chemical and hydraulic characteristics and mineral composition of soils; stress-strain-strength relationships; permeability; consolidation; shear strength; and lateral earth pressure. Students will apply knowledge of these fundamentals to solve civil and environmental engineering problems related to soil deformation, stability, and groundwater flow.

Prerequisites: 12-231 and 33-142

12-350 Special Topics: Design/Build: Urban Farming and Building Systems

Spring: 9 units

In this course, architecture and engineering students will work side-by-side as they design and build the building systems for an urban aquaponics farm and classroom that will be developed in a parallel architecture studio. Topics range from energy performance, including production, renewable energy systems, efficiency (both passive and active means), and modeling; integrated and smart structural and engineering systems, including building envelope, water treatment and management, heating and cooling systems, and electric and lighting systems; and sensing for monitoring and control. Students will learn the fundamentals of building systems and their interdependencies through lectures and readings, independent research, team-based design, and construction of the building.

12-351 Environmental Engineering

Spring: 9 units

Environmental engineering applies sustainability science, engineering principles, and systems approaches to protect the environment and human health. This includes protecting natural ecosystems and enhancing the quality of human life through environment-related policy development and technological innovation, and assessing the environmental impacts or benefits of infrastructure projects. This course provides a scientific and engineering basis for understanding and developing sustainable solutions for challenges in environmental and public health protection, especially in relation to urban water systems, with links to energy and climate. Topics covered include: sustainability; basic principles of water chemistry and microbiology; mass and energy balances; reactor theory and models; physical-chemical and biological processes; drinking water treatment; wastewater treatment; rivers, lakes, and ecosystems. Students will develop quantitative problem-solving skills for environmental engineering challenges. Students will also learn about and analyze current environmental and public health issues.

Prerequisites: 09-105 or 09-111

12-352 Environmental Engineering Lab

Spring: 3 units

Environmental engineering depends on many kinds of measurements as well as experimentation for monitoring and managing natural and engineered systems. In this course, students will design and conduct laboratory experiments that illustrate the fundamental principles of chemical, physical, and biological processes learned in environmental engineering. Topics include acid-base chemistry, carbonate chemistry, solids removal, and pathogen detection. Experiments include applications of methods to detect and quantify both inorganic and organic contaminants in water, and methods to remove contaminants from water. Students will also advance teamwork skills through group efforts and collaborative writing.

12-353 Environmental Biology and Ecology

Spring: 9 units

Profound changes are affecting our environment, including climate change, habitat loss, pollution, and invasive species. Understanding ecosystems and their inhabitants and functions is critical to engineering a sustainable future for humans. This course is an introduction to ecology and biology for environmental engineers. Ecology topics include the relationships among organisms and between organisms and their environment; and adaptations, populations, communities, and terrestrial and aquatic ecosystems. Biology subjects will focus on microbiology, as bacteria are an analog for more-complex species. Microbiology topics include biological molecules, biochemical reactions, energetics, diversity of microbial metabolism, physiology, biofilms, biogeochemical cycles, and the degradation of pollutants.

Prerequisite: 03-121

12-355 Fluid Mechanics

Fall: 9 units

The flow of fluids is important in many civil and environmental engineering applications ranging from water infrastructure and coastal engineering to bridge design. This course provides students with an introduction to fundamental concepts and methods in fluid mechanics. Topics covered in the course include fluid properties; pressure, hydrostatics, and buoyancy; open systems and control volume analysis; conservation of mass and momentum for moving fluids; viscous fluid flows and flow in conduits; dimensional analysis and similitude; open channel flows; lift and drag on immersed bodies; and differential analysis. Through application of these concepts, students will develop problem-solving skills and formulate models necessary to study, analyze, and design fluid systems essential to good engineering practice of fluid mechanics. Civil Engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.

Prerequisite: 21-260 Min. grade C

12-356 Fluid Mechanics Lab

Fall: 2 units

An understanding of fluid mechanics is greatly enhanced by hands-on experimentation and experience with the physical concepts of fluid flows. In this course, students will develop an ability to conduct experiments, take measurements, and analyze and interpret data in fluid mechanics. Topics covered include measurement of fluid properties; static forces on immersed surfaces; continuity and energy; viscous pipe flow; and open channel flow. Students will foster teamwork skills and an ability to creatively develop independent ideas around the description of fluid mechanics through small-group work with experimental apparatus and individual reports on the acquired data.

12-358 Materials Lab

Spring: 3 units

An understanding of the behavior and properties of materials used in the fields of civil and environmental engineering is developed through hands-on testing. Mechanical and physical properties and their variabilities will be studied for modern civil and environmental engineering materials. As part of a team, students will develop an ability to design and conduct experiments and analyze and interpret data related to material properties to solve realistic civil and environmental engineering problems. Students will practice team writing skills as they compose lab and other reports. Understanding of material properties will prepare students to assess the performance and fitness of new materials.

Prerequisite: 12-231

12-371 Advanced Computing and Problem Solving in Civil and Environmental Engineering

Spring: 9 units

Building upon the fundamentals developed in 12-271, this course introduces students to advanced topics in computational problem solving that are critical for implementing and interpreting computational solutions in civil and environmental engineering practice. These topics include numerical methods (both deterministic and stochastic) for approximation, differentiation, and integration in high dimensions; topics in numerical linear algebra for data science (including applications of QR factorization, singular-value decomposition, and Cholesky factorization); an introduction to clustering, regression, and classification; an introduction to statistical sampling; an introduction to graph and network theory; topics in deterministic and stochastic optimization; an introduction to scripting and automation; numerical solutions of ordinary differential equations (including finite differences and basic finite-element analysis); and practices for effective visualization of large data sets. Each topic is presented with real-world civil and environmental engineering problems, in areas such as smart cities, transportation, energy, buildings, and hydrology. An emphasis is placed on identifying the appropriate computational method for any specific problem; additional emphasis is placed on developing computational thinking. This course culminates in a project, which requires students to synthesize their computational reasoning skills in order to solve a challenging civil and environmental engineering problem.

Prerequisite: 12-271

12-401 CEE Design: Imagine, Build, Test

Fall: 12 units

This capstone design experience integrates knowledge and experience from technical and professional skills acquired in the CEE project course sequence. Students apply the design process and knowledge from the core curriculum to design engineering solutions to real engineering problems. Students work in teams in a pre-professional environment to meet the challenges with which they are presented. Oral, written, and graphic communications both within teams and to an external audience are essential to successful completion of the projects. Students manage the design-build process as they work on a semester-long project in this capstone design course. Student teams define the engineering problem, imagine and evaluate potential solutions, execute the engineering design, and build the project. The project is then tested against the established requirements and criteria.

Prerequisite: 12-301

12-411 Project Management for Engineering and Construction

Fall: 9 units

Through planning and management, and optimization and allocation of materials and labor under time and financial constraints, project managers lead teams to achieve project goals. This course is an introduction to project management of engineering, construction, and operations of building facilities and civil infrastructure. This course emphasizes design, construction, and operation as an integrated process and examines various topics related to four core aspects of project management - time, cost, quality, and safety. Engineering and management cases from civil, construction, and infrastructure engineering domains will be examined. Topics covered include contracting issues, legal structures, project planning and scheduling, cash flows, cost estimation and financing of constructed facilities, labor productivity, material management, equipment utilization, cost control, monitoring, and accounting for construction. The course will introduce various software tools useful for implementation of these topics, including project scheduling and management tools, software for optimization and economic analysis, field operation analysis tools, and digital design and modeling tools. Civil engineering undergraduates register for section A. Environmental Engineering undergraduates register for section B. All graduate students register for section C.

Prerequisite: 12-301

12-421 Engineering Economics

Fall: 6 units

Basic concepts of economic analysis and evaluation of alternative engineering projects for capital investment. Consideration of time value of money and common merit measures such as net present value and internal rate of return. Selection of independent projects and mutually exclusive proposals, using various methods of analysis. Capital budgeting and project financing. Influence of price level changes, depreciation and taxation on choice of alternatives. Uncertainty and risk in operation and financing. Important factors affecting investment decisions for private and public projects.

Prerequisite: 21-120 Min. grade C

12-451 Advanced Environmental Engineering

Spring: 9 units

Building on the fundamentals developed in 12-221, 12-351, and 12-353, students learn the fundamentals of design for physical, chemical, and biological processes used for pollution control, multi-phase transport, and transformation processes. Specific topics include unit analysis of physical, chemical, and biological processes; environmental hydraulics; water quality modeling; and water and waste treatment theory, analysis, and design. Also covered are system design challenges and opportunities around climate change, sustainability, and life-cycle assessment.

Prerequisites: 12-351 and 12-355 and 12-221 and 12-353

12-471 Applied Data Analytics for Civil and Environmental Systems

Spring: 9 units

Building upon the fundamentals developed in 12-271 and 12-371, this course empowers students to leverage computing tools for big data. Topics include design of experiments; advanced topics in statistics and uncertainty quantification; an introduction to signal processing and Fourier theory; an introduction to classification, clustering, and other concepts from machine learning; and an introduction to parallel and distributed computing and sensing. Each topic is presented in the context of a specific set of engineering problems. An emphasis is placed on identifying computationally appropriate and efficient solutions. This course culminates in a collaborative project, enabling students to synthesize their computational and data science skills to solve a significant problem in civil and environmental systems

Prerequisite: 12-371

12-600 AutoCAD

Fall and Spring: 3 units

AutoCAD is mostly held online. The course provides an introduction to the fundamentals of computer-aided design (CAD) software. Students learn how to set up CAD projects using Autodesk's AutoCAD software. Topics include coordinates, lines, circles, arcs, zooms, snaps and grids, text, views, layers, plines, blocks, reference files, dimensioning, isometrics, 3D commands, surfaces, solids, and more. CAD standards for layers, plotting, and symbol libraries are also covered. The course includes development of a CAD project by each student.

12-612 Intro to Sustainable Engineering

Fall: 9 units

This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems.

12-623 Molecular Simulation of Materials

Spring: 12 units

The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec.

12-629 Environmental Microbiology for Engineers

Fall: 9 units

This class provides a general introduction to microorganisms in natural and engineered environments. Selected topics include: cellular architecture, energetics and energy conservation, growth and catabolism; evolution and genetics; population and community dynamics; water and soil microbiology; biogeochemical cycling; biofilms; and microorganisms in wastewater, pollution attenuation, and bioremediation.

Prerequisite: 03-121

12-631 Structural Design

Spring: 12 units

Design of structural members for bending moment, shear force, axial force, and combined axial force and bending. Reinforced concrete, structural steel, and composite beam construction are considered. Buckling effects in columns, beams and local plate segments are treated. Serviceability limits such as deflection and cracking are addressed. Design projects include the determination of loads and the selection of system geometry.

Prerequisite: 12-231

12-635 Structural Analysis

Fall: 12 units

Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.

Prerequisite: 12-231

12-636 Geotechnical Engineering

Spring: 9 units

Behavior of geotechnical structures; engineering design of geotechnical structures considering failure modes; uncertainties; economic issues, required design formats and relevant code provisions; performance requirements for foundations, subsurface investigations; allowable stress and LRFD design approaches; reliability-based design; shallow foundations; deep foundations; retaining structures; reinforced concrete foundations.

Prerequisite: 12-335

12-638 Behavior of Structural Systems

Spring: 9 units

Students will learn how structural systems work, the rationale behind building design codes, and how to design structures that can resist complicated loads like wind and earthquakes. Topics include fundamental principles of structural design, common structural systems, methods for determining and applying loads to buildings, approximate methods of analysis, distribution of gravity and lateral loads, frames, shear walls, and structural details for steel and reinforced concrete. The conceptual design for a building is developed through a semester-long project.

Prerequisites: 12-631 or 12-635

12-644 Special Topics: Intro to Transportation Systems Analysis

Fall: 6 units

This course covers fundamentals of planning, design and operation of roadway transportation and public transportation. Topics covered include basic traffic flow theory, traffic signal design and evaluation, transportation planning, pricing of transportation systems, and basic data analytics techniques. The objective is to develop the capability to: 1) understand the principles of transportation planning, transportation economics and system management; 2) analyze transportation systems with emerging mobility data; and 3) apply methodologies to solve transportation system problems and develop management strategies/policies.

12-645 Smart Cities: Growth and Intelligent Transportation Systems

Fall: 6 units

Cities all around the world are being built and re-invented as smart cities utilizing information systems and innovative applications of data analytics. One major smart cities component is transportation. The Intelligent Transportation Systems (ITS) industry is expected to grow at a rate of 19% per year and reach \$5.5 Billion in annual investment by 2020. This shifting dynamic provides great opportunity for improved transportation safety and efficiency but also poses challenging information systems and public policy challenges. Furthermore, there are new opportunities for professional-school graduates outside of engineering schools for employment in transportation planning and policy. This course is supported by CMU's Traffic21 Initiative and Technologies for Safe and Efficient Transportation (T-SET) University Transportation Center. Classes will feature guest lectures provided by T-SET faculty and industry and government ITS professionals.

12-648 CEE Research Project

Fall and Spring

This course is designed to give students the opportunity to work on a research project under the direction of a faculty member in Civil and Environmental Engineering. A student in this course must write a proposal and submit progress reports to the advisor. The student must also make a presentation of the project results and submit a final report. To register for this course, a student must have the approval of the faculty member for both the research topic and the number of units.

12-651 Air Quality Engineering

Fall: 9 units

The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

12-657 Water Resource Systems Engineering

Spring: 9 units

Water Resource Systems Engineering combines hydrology, engineering, economics, and operations research to create tools and analyses that support decisions about large-scale water resource systems. The emphasis in this course will be on optimization methods, which are a core element of water systems analysis. Both water quantity and water quality problems will be covered.

Prerequisite: 12-355

12-659 Special Topics: Matlab

Fall: 6 units

This mini course is designed to be a practical introduction to engineering scientific computation. The topics of this class will include basic matrix computation, solving ordinary and partial differential equations, solving systems of linear equations, computing eigenvalues and eigenvectors, and basic signal processing and neural network techniques. Throughout the course, these scientific computation tools will be demonstrated using interactive scientific software called MATLAB.

12-676 Special Topics: Fundamental Concepts and Methods of Structural Mechanics

Fall: 12 units

This course will cover topics including an Introduction to Structural Dynamics, consisting of single degree-of-freedom systems, linear multi-degree-of-freedom systems, and relevant properties of symmetric matrices; Wave Propagation, consisting of Elements of Linear Elasticity, Formulation of Wave Propagation Problems, and Mathematical Aspects of Equations Relevant to Wave Propagation; and Elements of numerical methods applied to structural dynamics and wave propagation (if time permits).

12-679 Special Topics: Intro to Meteorology

Fall: 12 units

The course targets entering doctoral students in atmospheric research, as well as interested upper-level undergraduates (juniors and seniors) and masters students across engineering and sciences. It will provide students with the basics of meteorology, with a focus on large-scale atmospheric motion. By the end of the term students will understand the basics of atmospheric dynamics, including horizontal and vertical motion, as well as the vertical structure of the atmosphere (atmospheric stability and boundary-layer dynamics). They will understand what makes weather happen and they will understand weather maps and charts. They will be able to critically watch the nightly weather forecast and be able to access available meteorological databases to make informed predictions of their own. Finally, they will understand atmospheric transport and boundary-layer dynamics, which will serve as a foundation for other coursework involving atmospheric transport and air-pollution if they are pursuing those topics more deeply.

12-690 CEE Independent Study

Fall and Spring

In-depth investigation of a special topic in Civil and Environmental Engineering under the direction of a faculty member. The subject of study is determined through discussion between the student and a faculty advisor. A student in this course must write a proposal about what they want to learn and how it can be evaluated. Approaches can include more in-depth examination of topics in the curriculum, study of topics not in the curriculum, a design project, or other investigation. To register for this course, a student must have the approval of the faculty member for both the subject and the number of units.

12-702 Fundamentals of Water Quality Engineering

Fall: 12 units

This course is a systematic overview of water quality engineering designed for students with no prior civil and environmental engineering background. Topics examined include physical, chemical, and biological characteristics of water; common water pollutants; basic water chemistry and microbiology; mass and energy balances and their use in reactor analysis; physical, chemical and biological processes affecting natural water quality and the use of these processes in water supply and wastewater management systems; and selected problems in surface water and groundwater quality management. A background in college-level general chemistry, physics, calculus, and differential equations is assumed.

12-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units

Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty.

12-712 Sustainable Engineering Principles

Fall: 12 units

This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

12-714 Environmental Life Cycle Assessment

Spring: 12 units

Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

Prerequisites: (12-421 or 12-706) and 12-712

12-718 Environmental Engineering, Sustainability, and Science Project

Spring: 12 units

This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

12-719 Special Topics: AIS/EESS Project

Spring: 12 units

This course integrates and exercises students in a significant sustainable engineering and/or environmental project that is team-based and built upon the knowledge, skills, and technologies learned in the core and specialist courses in the EESS graduate curriculum.

12-720 Water Resources Chemistry

Fall: 12 units

This course provides a rigorous yet practical basis for applying the principles of physical chemistry to understanding the composition of natural waters and to the engineering of water and wastewater treatment processes. Topics covered include chemical equilibrium and kinetics; acid-base equilibria and buffering; solid precipitation and dissolution; oxidation and reduction reactions; adsorption on solids; and computer-aided problem solving. The primary objective of the course is to be able to formulate and solve chemical equilibrium models for complex aqueous systems. Knowledge of college-level general chemistry is assumed.

12-724 Biological Wastewater Treatment

Spring: 12 units

This course presents the application of microbiological systems for water and wastewater treatment. Fundamentals of modeling suspended growth and fixed film biological systems is followed by discussion of processes, including: aerobic heterotrophic growth, nitrification, denitrification, phosphorus removal, methanogenesis. Specific unit operations discussed include: activated sludge, trickling filters, fluidized beds, tertiary nutrient removal, and anaerobic digesters. In addition to the listed pre-reqs, taking 12-629 or 12-729 is helpful for the course.

Prerequisites: 12-702 and (12-720 or 12-725)

12-725 Fate, Transport & Physicochemical Processes of Organic Contaminants in Aquatic Systems

Spring: 12 units

Examination of the major physical and chemical processes affecting the fate and treatment of organic compounds and nanoparticles in aquatic systems. The emphasis is on anthropogenic organic compounds. The course will review some concepts from physical organic chemistry, and examine the relationships between chemical structure, properties, and environmental behavior of organic compounds. Chemical processes important to the fate, treatment, and biotransformation of specific organic compounds are addressed. Two laboratory sessions illustrate measurement techniques for organic compounds in water. 12-702 is a co-req for non environmental engineers or students who have not had an environmental engineering undergraduate course

12-726 Mathematical Modeling of Environmental Quality Systems

Spring: 12 units

Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk.

12-740 Data Acquisition

Fall: 6 units

The intent of this course is to introduce students to the concepts, approaches and implementation issues associated with data acquisition for infrastructure systems. Students will be introduced to the types of data that is collected about infrastructure systems, excitation mechanisms, sensing technologies, data acquisition using sensors, signal pre-processing and post-processing techniques, and use of sensing in a variety of applications in construction and infrastructure management. Students will also gain experience with data acquisition hardware and software.

12-741 Data Management

Fall: 6 units

The intent of this course is to introduce students to database management systems and to knowledge discovery in database principles. Students will learn how to develop powerful tools for efficiently managing large amounts of civil engineering data so that it may persist safely over long periods of time. Students will be introduced to relational database systems and structured query languages. They will also be exposed to other existing data models. Students also will be introduced to data mining and analysis tools to discover patterns and knowledge from data.

12-746 Special Topics: Introduction to Python Prototyping for Infrastructure Systems

Fall: 6 units

This course uses the Python programming language to introduce fundamental programming approaches to students from civil and environmental engineering. No prerequisite required and students with no programming experience are recommended to take this course. This course will cover fundamental programming approaches, object-oriented programming concepts, graphical user interface design in Python, and file and database operation. Real-world examples from infrastructure management will be used in the class for demonstration and term project. Students will work individually and in teams to develop a series of applications that are potentially be used in real-world applications.

12-748 Mechanical and Electrical System Design for Buildings

Fall: 6 units

Class will cover HVAC, Electrical, and Plumbing systems for buildings. We will calculate heat loss and heat gains manually and with computer programs and calculate operating costs with various fuels and system types. We will size building electrical systems and look at alternative generation, smart metering and new lighting systems. Plumbing will include sizing water, drain and vent lines along with system design. Focus of the class will be on energy conservation and use, and how future systems will meet this criteria. The final project will be the audit of a building on campus using what we learned. Graduate Standing, or approval of instructor.

12-749 Climate Change Adaptation

Fall: 6 units

While the specific timing and magnitude of climate change impacts are uncertain, long-lived civil engineering infrastructure will need to be resilient to these potential impacts. Engineers designing for climate change adaptation require the tools to maximize resiliency and minimize cost for existing and proposed energy, transportation, water, urban and other types of infrastructure. Students successfully completing this course will understand how climate change affects civil infrastructure and how to quantitatively incorporate resilient designs and co-benefits under uncertainty. Students will use open data to examine current adaptation engineering challenges, quantify solutions, and communicate their technical recommendations through policy briefs. Prerequisites: Graduate standing or consent of instructor.

12-755 Finite Elements in Mechanics I

Fall: 12 units

The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow, and others. Introduction to advanced topics, including fourth-order equations, time dependence, and nonlinear problems. Prerequisite: Graduate standing or consent of instructor. Prerequisites: Graduate standing or consent of instructor.

Department of Electrical and Computer Engineering

Lawrence Pileggi, Coraluppi Head and Tanoto Professor

James Bain, Associate Head, Academic Affairs

Shawn Blanton, Associate Head, Research

Tamal Mukherjee, Associate Head, Students
www.ece.cmu.edu (<http://www.ece.cmu.edu>)

The field of electrical and computer engineering encompasses a remarkably diverse and expanding set of technologies, including embedded systems, intelligent physical systems, real-time software, distributed computing, mobile computing, cloud computing, digital signal processing, integrated circuits and electronics, computer architecture, intelligent robotic systems, computer-based control systems, telecommunications, computer networking, wireless communication systems, signal and information processing, multimedia systems, solid state physics and devices, microelectromechanical systems (MEMS), electromagnetic and electromechanical systems, and data storage systems. The extraordinary advances in these technologies during the last fifty years have impacted nearly every aspect of society and human activity. These advances have created new products and markets such as "smart" cars, cell phones and mobile computing systems, video games, and advanced medical systems for imaging, diagnosis, testing, and monitoring. These systems and products have served to enhance our quality of life and have also fueled the global economy. In short, the field of electrical and computer engineering has become central to society as we know it.

The Department of Electrical and Computer Engineering at Carnegie Mellon is actively engaged in education and research at the forefront of the existing and emerging technologies. Because of the diverse and broad nature of the field and the significant growth in knowledge in each of its sub areas, it is no longer possible for any single individual to know all aspects of electrical and computer engineering. Nevertheless, it is important that all electrical and computer engineers have a solid knowledge of the fundamentals with sufficient depth and breadth. Society is placing increasing demands on our graduates to apply their skills in new contexts. It is also placing increasing value on engineers who can cross traditional boundaries between disciplines and who can intelligently evaluate the broader consequences of their actions. Our curriculum is designed to produce world-class engineers who can meet these challenges.

Educational Outcomes and Objectives

The B.S. in Electrical and Computer Engineering is a broad and highly flexible degree program structured to provide students with a rich and comprehensive view of the profession. Minimal curriculum constraints enable every student to construct their own unique program of study that fits their professional goals. Students are encouraged to explore multiple areas of theory and application. Our program is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org> (<http://www.abet.org/>). The Faculty of Electrical and Computer Engineering have adopted the following outcomes from ABET and have established the following objectives for the B.S. in Electrical and Computer Engineering curriculum:

Educational Outcomes

1. An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. An ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. An ability to communicate effectively with a range of audiences
4. An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

ECE Education Objectives

The ECE program objectives are shown below. They represent our vision for what our students will be doing in their engineering careers five years after they have graduated. The principal behaviors we seek to foster in our students are *expertise*, *innovation* and *leadership*. Our graduates will be:

Experts

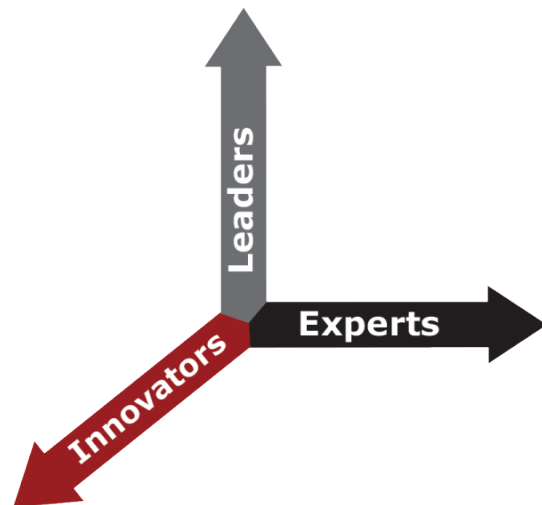
- They will solve problems by applying ECE fundamentals
- Their solutions will reflect depth of understanding in their sophistication.
- Their solutions will reflect breadth of understanding by drawing on multiple disciplines.

Innovators

- They will demonstrate creativity in their engineering practice.
- They will consider holistic systems-oriented approaches in their designs.
- They will think strategically in their planning and execution.

Leaders

- They will take initiative, and demonstrate resourcefulness.
- They will collaborate in multidisciplinary teams.
- They will be leaders in their organizations, their profession and in society.



Three dimensions of objectives for our graduates.

Curriculum Overview

The B.S. in Electrical and Computer Engineering is a broad and highly flexible ABET-accredited (<http://www.abet.org>) degree program structured to provide students with the smallest set of constraints consistent with a rich and comprehensive view of the profession. Students are encouraged and stimulated to explore multiple areas of theory and application from across the 5 principal undergraduate areas (<https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html>) of Electrical and Computer Engineering. The sample curriculum (<http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/departmentofelectricalandcomputerengineering/#samplecurriculumtext>) highlights the flexibility of our curriculum while meeting the requirements listed below

Minimum total units required for B.S. in Electrical and Computer Engineering **379**

For detailed information and regulations of the curriculum along with the degree requirements and the most recent version of the ECE curriculum and course descriptions, please refer to the ECE Academic Guide (<http://www.ece.cmu.edu/programs-admissions/bachelors/academic-guide/>).

University Requirement

| | Units |
|------------------------------------|----------|
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 3 |

CIT Requirements (see CIT section of the catalog for specifics (p. 70)):

| | Units |
|--|------------|
| CIT General Education | 72 |
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| One other introductory engineering course (generally taken during the freshman year) | 12 |
| 33-141 Physics I for Engineering Students | 12 |
| 33-142 Physics II for Engineering and Physics Students | 12 |
| 15-112 Fundamentals of Programming and Computer Science | 12 |
| | 140 |

GENERAL TECHNICAL REQUIREMENTS:

| | Units |
|--|-----------|
| Two Math/Science electives ¹ | 18 |
| Probability Requirement | |
| 21-325 Probability | 9 |
| or 36-219 Probability Theory and Random Processes | |
| or 36-225 Introduction to Probability Theory | |
| 18-202 Mathematical Foundations of Electrical Engineering ² | 12 |
| 21-127 Concepts of Mathematics ³ | 12 |
| or 21-128 Mathematical Concepts and Proofs | |
| 15-122 Principles of Imperative Computation | 10 |
| | 61 |

¹The Math/Science Electives may be satisfied by any course in The Mellon College of Science or the Department of Statistics except for: 100-level courses in Mathematics or Statistics, and courses designed for non-science or engineering majors, such as (but not limited to) 09-103, 09-104, 21-240, 21-257, 33-115, 33-120, 33-124, 36-201, 36-202, 36-203, 36-207, 36-208, 36-209, 36-210, 36-247, 36-309, 36-310. Mathematics courses of particular interest to students in ECE are: 21-228 Discrete Mathematics, 21-241 Matrices and Linear Transformations, 21-259 Calculus in Three Dimensions, 21-260 Differential Equations.

²This course can also be substituted by a combination of two of the following courses: 21-254, 21-259, 21-260, 21-241, 21-242, 21-268. Note that the combined total will therefore be 18 units.

³Effective Fall 2022. Prior to Fall 2022, 21-127 was 10 units.

ECE COURSE requirements:

For detailed information and regulations along with the degree requirements and the most recent version of the ECE curriculum and course descriptions,

please refer to the ECE Academic Guide (<https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html>).

| | Units |
|---|------------|
| ECE CORE COURSES | |
| 18-100 Introduction to Electrical and Computer Engineering | 12 |
| 18-200 ECE Sophomore Seminar | 1 |
| 18-213 Introduction to Computer Systems | 12 |
| 18-220 Electronic Devices and Analog Circuits | 12 |
| 18-240 Structure and Design of Digital Systems | 12 |
| 18-290 Signals and Systems | 12 |
| ECE AREA COURSES | |
| Two Area Courses from 1 of the 5 Areas within ECE | 24 |
| One additional Area Course from a second Area | 12 |
| ECE COVERAGE COURSES | |
| One Coverage Course (any additional ECE course or Approved CS course as listed on the ECE web site) | 12 |
| ECE CAPSTONE DESIGN | |
| Any 18-5xx course | 12 |
| | 121 |

FREE ELECTIVES 54 units (typ)*

*For most students, the curriculum above will result in a remainder of 54 units of free electives to achieve the 379 required total units.

A Free Elective is defined as any graded course offered by any academic unit of the university (including research institutes such as the Robotics Institute (<http://www.ri.cmu.edu/>) and S (<https://s3d.cmu.edu/>)/3D (<https://s3d.cmu.edu/>)).

Up to 9 units of Student Taught Courses (StuCO) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Transfer of courses from other high-quality universities may be accepted through submission of the Transfer Credit Request form on the CIT web page (https://engineering.cmu.edu/education/academic-policies/undergraduate-policies/transfer_credit/). Please see the CIT website (<https://engineering.cmu.edu/education/academic-policies/undergraduate-policies/transfer-credit.html>) for further information regarding the process.

The large number of units without categorical constraints provides the student, in consultation with their Advisor or Mentor, with the flexibility to design a rich educational program.

Sample Curriculum

The table below shows a possible roadmap through our broad and flexible curriculum. The ECE Academic Guide (<https://www.ece.cmu.edu/academics/bs-in-ece/academic-guide.html>) provides further alternatives.

For First-Year requirements, please see CIT section of the catalog for specifics (<http://coursecatalog.web.cmu.edu/schools-colleges/collegeofengineering/#firstyearforengineeringstudentstext>).

| First-Year | | Second-Year | |
|--|---|---|---|
| Fall | Spring | Fall | Spring |
| 18-100 Introduction to Electrical and Computer Engineering | Introductory Engineering Course | 18-200 ECE Sophomore Seminar | 18-2xx ECE Core course |
| 15-112 Fundamentals of Programming and Computer Science | 33-141 Physics I for Engineering Students | 18-2xx ECE Core Course | 21-127 Concepts of Mathematics or 18-202 Mathematical Foundations of Electrical Engineering |
| 21-120 Differential and Integral Calculus | 21-122 Integration and Approximation | 18-202 Mathematical Foundations of Electrical Engineering | 15-122 Principles of Imperative Computation |
| 76-101 Interpretation and Argument | General Education course | General Education course | 36-219 Probability Theory and Random Processes |
| 99-101 Computing @ Carnegie Mellon | | 33-142 Physics II for Engineering and Physics Students | General Education course |
| | | 39-210 Experiential Learning I | 39-220 Experiential Learning II |

| Third-Year | | Fourth-Year | |
|---|---|---|-----------------------------------|
| Fall | Spring | Fall | Spring |
| 18-2xx ECE Core course | 18-2xx ECE Core course | 18-xxx ECE Coverage course | 18-5xx ECE Capstone Design course |
| 18-3xx/4xx ECE Area 1 course (first course in Area) | 18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course) | 18-3xx/4xx ECE Area course (either 2nd course from Area 1 or the Area 2 course) | General Education course |
| General Education course | Math/Science Elective 2 | General Education course | Free Elective |
| Math/Science Elective 1 | General Education course | Free Elective | Free Elective |
| Free Elective | Free Elective | Free Elective | Free Elective |
| 39-310 Experiential Learning III | | | |

Academic Policies

Policy on ECE Coverage Courses with Fewer than 12 Units

The basic curriculum requirements for Area courses, Coverage and Capstone Design are stated in terms of courses rather than units. The nominal total of 60 units for these categories is determined by assuming that each course is 12 units. In the event that courses with fewer than 12 units are used to satisfy some or all of these requirements, additional courses from the ECE coverage lists must be taken until the total units in ECE courses beyond the core meets or exceeds 60 units. Any ECE coverage course is acceptable, and any excess units beyond the required 60 may be counted as free elective credit.

Prerequisite Grade Requirements

Many ECE courses require a prerequisite course or courses. In most cases, the minimum grade required in a prerequisite to proceed on to the next course is a C. All prerequisites are listed in the registration system.

QPA Requirement and Overload Policy

An overload is defined as any schedule with more than 54 units in one semester. A student will only be permitted to overload by 12 units if she or he achieved an overall QPA of at least 3.5 out of 4.0. If the student's overall QPA is below a 3.5, then the QPA of the previous semester for which he or she is registering will instead be utilized. If that QPA is at least a 3.5 then the student will be permitted to Overload.

Grade Policy for Math Courses

1. CIT states that all mathematics (21-xxx) courses required* for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.
2. A minimum grade of C must be achieved in any required mathematics (21-xxx) course that is a prerequisite for the next higher level required mathematics (21-xxx) course.
3. In addition, ECE requires that 18-202 Mathematical Foundations of Electrical Engineering must be completed with a grade of C or better.

*Elective mathematics courses (like the math/science electives required for ECE) are not included in this policy

Pass/Fail policy

Up to 9 units of StuCo and/or Physical Education courses or other courses taken as Pass/Fail may be used toward Free Electives. ECE core courses may not be taken as pass/fail. ECE project-based courses (including capstone design courses) may not be taken pass/fail. No ECE requirements may be fulfilled using a pass/fail course (except for 99-10x and 18-200)

Other Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Students are encouraged to confirm all graduation requirements with their academic advisor.

CIT has the following requirement for graduation. "Students must complete the requirements for their specified degrees with a cumulative quality point average of 2.00 or higher for all courses taken after the freshman year [this

is the CIT QPA on the Academic Audit]. In addition, a student is expected to achieve a cumulative quality point average of 2.00 in a series of core departmental courses."

In ECE, this means that the student must complete 18-100 Introduction to Electrical and Computer Engineering, ECE Core, Area Courses, Coverage, and Capstone Design courses with a minimum QPA of 2.0 to graduate. When more than one possibility exists for meeting a specific requirement (e.g., Area Course), the courses used for calculating the ECE QPA will be chosen so as to maximize the QPA. Similarly, when an ECE course is retaken, the better grade will be used in the computation of the minimum QPA for the ECE QPA requirement to graduate.

Other Opportunities in ECE

ECE Cooperative Education Program

Our Cooperative Education Program invites students to gain valuable experience in employment that relates directly to their major and career goals. At the same time, it provides employers with opportunities to evaluate students as potential full-time employees, while having them complete meaningful projects. Participation in this program is voluntary, and obtaining a cooperative education assignment is competitive.

Due to federal restrictions on student work experiences, international students are not eligible for co-ops. Please visit the ECE CPT page (<http://www.ece.cmu.edu/programs-admissions/bachelors/cpt.html>) for information regarding international student internships.

The co-op experience

We require a minimum of eight months of co-op experience to identify the work experience as a co-op. Students must have minimally completed their sophomore year to qualify for application to a co-op and should connect with their Academic Advisor for information on how to apply. While on co-op assignment, students are participating in a recognized CIT educational program, retaining their full-time student status, akin to our students who study abroad in established exchange programs (such as EPFL) for one or two semesters. The Cooperative Education Program agreement may be discontinued if the employers do not provide the students with career-related work experience or if the students do not meet the accepted level of performance as defined by the employers.

Upon returning to Carnegie Mellon, the students are required to submit for approval the following two documents to the ECE Undergraduate Office: a three to five page technical report of the Co-Op work, and a one page assessment and evaluation of the Co-Op experience.

Students may obtain more detailed information through the ECE department (<http://www.ece.cmu.edu/programs-admissions/bachelors/cooperative-education-program.html>) or the Career and Professional Development Center (<http://www.cmu.edu/career/>).

Teaching Assistantships

Teaching Assistants are a vital part of successful ECE course delivery. All ECE students will receive an email each semester when applications open for the upcoming semester, typically around the date the Schedule of Classes is published. Students are encouraged to communicate with the faculty of any course(s) they are interested in supporting, who can discuss the course expectations and staffing needs. Please see the ECE Teaching Assistantship website (<https://www.ece.cmu.edu/insider/teaching-opportunities.html>) for further information regarding these opportunities and how to apply.

Integrated M.S./B.S. Degrees Program

The Integrated Master's/Bachelor's program (<http://www.ece.cmu.edu/programs-admissions/integrated/>) (otherwise known as the IMB program) is an exciting opportunity for students who excel academically to achieve not just a Bachelor's degree in ECE, but also a Master's degree- through our Professional MS degree program-without needing to apply separately.

This means no application fee, and no need to take the GRE (Graduate Record Exam). In order to be awarded the MS degree in the IMB program, the student must also earn their BS degree, either simultaneously with the MS degree or at least one semester prior to the awarding of the MS degree. If a course is eligible for the MS degree but must be used to complete the BS degree, the BS degree takes priority over the MS degree.

If a student is at least a 2nd semester junior, has completed at least 270 units and has at least an overall 3.00 QPA, he or she is guaranteed admission into the Professional MS degree in ECE through the IMB program. To be officially admitted, the student must complete the IMB Program form.

If a student does not meet the exact overall 3.00 QPA requirement, he or she is eligible to petition for his or her admission into the IMB program

during his or her senior year. Students may obtain the petition forms through a meeting with their assigned academic advisor.

Professional MS Degree Requirements:

Please see the ECE web site for the requirements for the Professional MS degree (<http://www.ece.cmu.edu/programs-admissions/masters/ms-requirements.html>). For students in the ECE IMB program, all requirements for the Professional MS degree are in addition to the requirements for the BS in ECE. No requirements for the MS degree may be used in any way toward the BS degree, including minors, additional majors or dual degrees.

Residency requirements and financial impacts:

Once a student in the IMB program has completed all of the requirements for the BS degree and it is certified, the student will officially graduate with the BS degree and the student will be in graduate status for the subsequent term of enrollment. Once a student's undergraduate degree has been certified, no more courses may then be applied toward the BS degree. This includes courses toward minors and additional majors, although students pursuing an undergraduate dual degree with another department may still continue to apply additional coursework toward that second degree. Students should consult with Enrollment Services to understand how entering graduate status will affect financial aid, and with their academic advisor to determine a course schedule.

If a student takes more than 8 semesters to complete both the BS and MS degrees, then he or she must be in graduate status for at least one semester before graduating with the MS degree.

Faculty

GEORGE AMVROSIADIS, Assistant Research Professor of Electrical and Computer Engineering - Ph.D., University of Toronto, Canada; Carnegie Mellon, 2018-

JIM BAIN, Associate Department Head for Academic Affairs and Professor of Electrical and Computer Engineering and Materials Science Engineering; Associate Director, DSSC - Ph.D., Stanford University; Carnegie Mellon, 1993-

LUJO BAUER, Professor of Electrical and Computer Engineering - Ph.D., Princeton University; Carnegie Mellon, 2005-

THEO BENSON, Professor of Electrical and Computer Engineering - Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2022-

VIJAYAKUMAR BHAGAVATULA, U.A. and Helen Witaker Professor of Electrical and Computer Engineering, Affiliated Faculty, DSSC - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1982-

SHAWN BLANTON, Associate Department Head for Research; Joseph F. and Nancy Keithley Professor of Electrical and Computer Engineering - Ph.D., University of Michigan; Carnegie Mellon, 1995-

DAVID BRUMLEY, Professor of Electrical and Computer Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008-

MARK BUDNIK, Teaching Professor of Electrical and Computer Engineering - Ph.D., Purdue University; Carnegie Mellon, 2021-

L. RICHARD CARLEY, Professor of Electrical and Computer Engineering; Affiliated Faculty, DSSC - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1984-

MAYSAM CHAMANZAR, Dr. William D. and Nancy W. Strecker Career Development Associate Professor, Electrical and Computer Engineering - Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2015-

VANESSA CHEN, Assistant Professor of Electrical and Computer Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019-

YUEJIE CHI, Professor of Electrical and Computer Engineering - Ph.D., Princeton University; Carnegie Mellon, 2018-

MARC DANDIN, Assistant Professor of Electrical and Computer Engineering - Ph.D., University of Maryland, College Park; Carnegie Mellon, 2019-

HAKAN ERDOGMUS, Teaching Professor of Electrical and Computer Engineering; Carnegie Mellon University Silicon Valley - Ph.D., Université du Québec; Carnegie Mellon, 2014-

GIULIA FANTI, Assistant Professor of Electrical and Computer Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 2017-

GARY FEDDER, Howard M. Wilkoff Professor of Electrical and Computer Engineering; Co-Director MEMS, Affiliated Faculty DSSC - Ph.D., University of California at Berkeley; Carnegie Mellon, 1994-

FRANZ FRANCHETTI, Kavčić-Moura Professor of Electrical and Computer Engineering; Associate Dean for Research, College of Engineering, Director

Engineering Research Accelerator - Ph.D., Vienna University of Technology; Carnegie Mellon, 2001-

GREGORY R. GANGER, Jatras Professor of Electrical and Computer Engineering; Director Parallel Data Lab - Ph.D., University of Michigan; Carnegie Mellon, 1997-

PHILLIP GIBBONS, Professor of Electrical and Computer Engineering and Computer Science - Ph.D., University of California at Berkeley; Carnegie Mellon, 2015-

VIRGIL GLIGOR, Professor of Electrical and Computer Engineering; Co-Director CyLab - Ph.D., University of California at Berkeley; Carnegie Mellon, 2008-

PULKIT GROVER, Angel Jordan Professor of Electrical and Computer Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 2013-

ASSANE GUEYE, Assistant Teaching Faculty Professor of Electrical and Computer Engineering; Carnegie Mellon University Africa - Ph.D., University of California at Berkeley; Carnegie Mellon, 2020-

JAMES HOE, Professor of Electrical and Computer Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000-

LIMIN JIA, Associate Research Professor of Electrical and Computer Engineering; Affiliated Faculty CyLab - Ph.D., Princeton University; Carnegie Mellon, 2013-

CARLEE JOE-WONG, Robert E. Doherty Career Development Professor of Electrical and Computer Engineering - Ph.D., Princeton University; Carnegie Mellon, 2016-

GAURI JOSHI, Associate Professor of Electrical and Computer Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017-

SOUMMYA KAR, Professor of Electrical and Computer Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2011-

GREGORY KESDEN, Teaching Professor of Electrical and Computer Engineering - MCS, Clemson University; Carnegie Mellon, 2017-

HYONG S. KIM, Drew D. Perkins Professor of Electrical and Computer Engineering; Director CMU-Thailand - Ph.D., University of Toronto; Carnegie Mellon, 1990-

PHILIP J. KOOPMAN, Associate Professor of Electrical and Computer Engineering and Computer Science - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1989-

SWARUN S. KUMAR, Associate Professor of Electrical and Computer Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2015-

QING LI, Associate Professor of Electrical and Computer Engineering - Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2018-

TZE MENG LOW, Associate Research Professor of Electrical and Computer Engineering - Ph.D., University of Texas at Austin; Carnegie Mellon, 2013-

BRANDON LUCIA, Sathaye Family Foundation Career Development Professor of Electrical and Computer Engineering - Ph.D., University of Washington; Carnegie Mellon, 2014-

KEN MAI, Principal Systems Scientist of Electrical and Computer Engineering - Ph.D., Stanford University; Carnegie Mellon, 2005-

CRAIG MILLER, Research Professor of Electrical and Computer Engineering - Ph.D., University of Michigan; Carnegie Mellon, 2020-

M. GRANGER MORGAN, Professor of Electrical and Computer Engineering; Hamerschlag University Professor of Engineering and Public Policy - Ph.D., University of California at San Diego; Carnegie Mellon, 1974-

JOSÉ M. F. MOURA, Philip L. and Marsha Dowd University Professor of Electrical and Computer Engineering - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1986-

TAMAL MUKHERJEE, Associate Department Head for Students and Professor of Electrical and Computer Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996-

WILLIAM NACE, Teaching Professor of Electrical and Computer Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008-

YORIE NAKAHIRA, Assistant Professor of Electrical and Computer Engineering - Ph.D., California Institute of Technology; Carnegie Mellon, 2020-

PRIYA NARASIMHAN, Professor of Electrical and Computer Engineering - Ph.D., University of California at Santa Barbara; Carnegie Mellon, 2001-

ROHIT NEGI, Professor of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–

DAVID O'HALLARON, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., University of Virginia; Carnegie Mellon, 1989–

AMRITANSHU PANDEY, Systems Scientist of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

BRYAN PARNO, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

GIANLUCA PIAZZA, STMicroelectronics Professor of Electrical and Computer Engineering; Director of Nanofab – Ph.D., University of California at Berkeley; Carnegie Mellon, 2012–

LAWRENCE T. PILEGGI, Coraluppi Head and Tanoto Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–

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GUANNAN QU, Assistant Professor of Electrical and Computer Engineering – Ph.D., Harvard University; Carnegie Mellon, 2021–

RAJ RAJKUMAR, George Westinghouse Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1992–

BARRY RAWN, Associate Teaching Professor of Electrical and Computer Engineering – Ph.D., University of Toronto; Carnegie Mellon, 2018–

ANTHONY ROWE, Siewiorek and Walker Family Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

WILLIAM SANDERS, Dr. William D. and Nancy W. Strecker Dean, College of Engineering Professor for Electrical and Computer Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2020–

ASWIN SANKARANARAYANAN, Professor of Electrical and Computer Engineering – Ph.D., University of Maryland; Carnegie Mellon, 2013–

MARIOS SAVVIDES, Bossa Nova Robotics Professor of Artificial Intelligence for Electrical and Computer Engineering; Director CyLab Biometrics Center – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

VYAS SEKAR, Tan Family Professor of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013–

JOHN SHEN, Distinguished Service Professor of Electrical and Computer Engineering – Ph.D., University of Southern California; Carnegie Mellon, 2015–

ELAINE SHI, Associate Professor of Electrical and Computer Engineering and Computer Science – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2020–

MICHAEL SKIRPAN, Special Faculty Instructor for Electrical and Computer Engineering; Executive Director, Community Forge – Ph.D., Colorado University at Boulder; Carnegie Mellon, 2019–

ASIM SMILAGIC, Research Professor of Electrical and Computer Engineering – Ph.D., University of Sarajevo, Bosnia and Herzegovina; Carnegie Mellon, 1988–

LEONARDO DA SILVA SOUSA, Assistant Teaching Professor of Electrical and Computer Engineering; Carnegie Mellon University Silicon Valley – Ph.D., Pontificia Universidade Católica do Rio de Janeiro; Carnegie Mellon, 2020–

AKSHITHA SRIRAMAN, Assistant Professor of Electrical and Computer Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2021–

PETER STEENKISTE, Professor of Electrical and Computer Engineering and Computer Science – Ph.D., Stanford University; Carnegie Mellon, 1987–

RICHARD STERN, Professor of Electrical and Computer Engineering; Language Technologies Institute, Computer Science, and BioMedical Engineering; Lecturer Music – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1977–

THOMAS SULLIVAN, Teaching Professor of Electrical and Computer Engineering; Lecturer Music – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1996–

OZAN TONGUZ, Professor of Electrical and Computer Engineering – Ph.D., Rutgers University; Carnegie Mellon, 2000–

ELIAS TOWE, Professor of Electrical and Computer Engineering; Grobstein Professor of Materials Science and Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–

RAFAL WLODARSKI, Assistant Teaching Professor of Electrical and Computer Engineering; Carnegie Mellon University Silicon Valley – Ph.D., Lodz University of Technology, Poland; Carnegie Mellon, 2022–

OSMAN YAĞAN, Associate Research Professor of Electrical and Computer Engineering – Ph.D., University of Maryland at College Park; Carnegie Mellon, 2013–

ZIAD YOUSSEFI, Associate Professor of Electrical and Computer Engineering – Ph.D., Michigan State University; Carnegie Mellon, 2022–

BYRON YU, Professor of Electrical and Computer Engineering; Gerard G. Elia Career Development Professor of Biomedical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2009–

TOM ZAJDEL, Assistant Teaching Professor of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2021–

XU ZHANG, Assistant Professor of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2019–

SIYANG ZHENG, Professor of Electrical and Computer Engineering and Biomedical Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2019–

JIMMY (JIAN-GANG) ZHU, ABB Professor of Electrical and Computer Engineering; Director DSSC; Professor of Materials Science and Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 1997–

Courtesy

YURVRAJ AGARWAL, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2013–

BURCU AKINCI, Paul Christiano Professor and Department Head, Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2022–

NATHAN BECKMANN, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

SARAH BERGBREITER, Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–

MARIO BERGES, Assistant Professor of Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

TIMOTHY X. BROWN, Distinguished Service Professor of Engineering and Public Policy, Director of Academics Carnegie Mellon University Africa; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2013–

KATHLEEN CARLEY, Professor of Computer Science and Institute for Software Research; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Harvard University; Carnegie Mellon, 2011–

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NICOLAS CHRISTIN, Professor of Computer Science (Software and Societal Systems Department) and Engineering & Public Policy; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Virginia; Carnegie Mellon, 2005–

LORRIE FAITH CRANOR, Associate Department Head and FORE Systems Professor of Engineering and Public Policy; Director CyLab Usable Privacy and Security Laboratory; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Washington University; Carnegie Mellon, 2008–

JOHN DOLAN, Senior Systems Scientist of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006–

KATHERINE FLANIGAN, Assistant Professor of Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2020–

MATT FREDRICKSON, Assistant Professor of Institute of Software Research; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2016–

IOANNIS GKIOULEKAS, Assistant Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Harvard University; Carnegie Mellon, 2017–

- BIN HE, Trustee Professor of Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Tokyo Institute of Technology; Carnegie Mellon, 2018–
- FARNAM JAHANIAN, President of Carnegie Mellon University; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2014–
- B. REEJA JAYAN, Assistant Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–
- AARON JOHNSON, Assistant Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2014–
- JANA KAINERSTORFER, Assistant Professor of Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Vienna/NIH; Carnegie Mellon, 2015–
- SHAWN KELLY, Senior Systems Scientist of Engineering Research Accelerator; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2012–
- KRIS KITANI, Assistant Research Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Tokyo; Carnegie Mellon, 2011–
- ZICO KOLTER, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2012–
- DAVE LAUGHLIN, ALCOA Professor of Materials Science Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–
- PHILIP LEDUC, William J. Brown Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Johns Hopkins University; Carnegie Mellon, 2002–
- CHANGLIE LIU, Assistant Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2019–
- SARA MAJETICH, Professor of Physics; Courtesy Faculty of Electrical and Computer Engineering; Affiliated Faculty DSSC – Ph.D., University of Georgia; Carnegie Mellon, 2010–
- CARMEL MAJIDI, Clarence H. Adamson Associate Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2011–
- ZACHARY MANCHESTER, Assistant Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Cornell University; Carnegie Mellon, 2020–
- FLORIAN METZE, Associate Research Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Dr.-Ing., Fakultät für Informatik der Universität Karlsruhe, Germany; Carnegie Mellon, 2009–
- TODD MOWRY, Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering; – Ph.D., Stanford University; Carnegie Mellon, 1997–
- SRINIVASA NARASIMHAN, Associate Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Columbia University; Carnegie Mellon, 2016–
- MATTHEW O'TOOLE, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Toronto; Carnegie Mellon, 2018–
- CORINA PASAREANU, Senior Research Scientist, Carnegie Mellon University Silicon Valley; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Kansas State University; Carnegie Mellon, 2015–
- JON M. PEHA, Professor of Engineering and Public Policy; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1991–
- ANDRE PLATZER, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Oldenburg, Germany; Carnegie Mellon, 2010–
- SEAN QIAN, Henry Posner, Anne Molloy, and Robert and Christine Pietrandrea Associate Professor of Civil and Environmental Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Davis; Carnegie Mellon, 2014–
- BHIKSHA RAJ RAMAKRISHNAN, Professor of Language Technologies Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–
- RAJ REDDY, Mozah Bint Nasser University Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2000–
- MAJD SAKR, Teaching Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pittsburgh; Carnegie Mellon, 20015–
- MAHADEV SATYANARAYANAN, Carnegie Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1983–
- SEBASTIAN SCHERER, Associate Research Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–
- JEFF SCHNEIDER, Research Professor of Robotics Institute; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Rochester; Carnegie Mellon, 2013–
- SRINIVASAN SESHAN, Associate Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2000–
- NIHAR SHAH, Assistant Professor of Machine Learning; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–
- SHENG SHEN, Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–
- JUSTINE SHERRY, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–
- BARBARA SHINN-CUNNINGHAM, Professor of Auditory Neuroscience of Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2018–
- RAMTEEN SIOSHANSI, Professor of Engineering and Public Policy; Director of the Carnegie Mellon Electricity Industry Center; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2023–
- MARVIN A. SIRBU, Professor of Engineering and Public Policy; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1985–
- DIMITRIOS SKARLATOS, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2020–
- VIRGINIA SMITH, Assistant Professor of Machine Learning; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–
- PATRICK TAGUE, Associate Director of the INI; Courtesy Faculty of Electrical and Computer Engineering; Carnegie Mellon University Silicon Valley – Ph.D., University of Washington; Carnegie Mellon, 2009–
- REBECCA TAYLOR, Assistant Professor of Mechanical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–
- SRIDHAR TAYUR, Professor of Tepper School of Business; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Cornell University; Carnegie Mellon, 2017–
- RASHMI VINAYAK, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–
- WEINA WANG, Assistant Professor of Computer Science; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., Arizona State University; Carnegie Mellon, 2018–
- SHINJI WATANABE, Associate Professor of Language Technologies Institute; Courtesy Professor, Electrical and Computer Engineering – Ph.D., Waseda University, Tokyo, Japan; Carnegie Mellon, 2020–
- SOSENA WOOD, Presidential Post-Doctoral Fellow of Biomedical Engineering; Courtesy Faculty of Electrical and Computer Engineering – Ph.D., University of Pittsburgh; Carnegie Mellon, 2022–

Department of Electrical and Computer Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

18-059 Introduction to Amateur Radio

Fall and Spring: 3 units

Amateur radio is a pursuit that encompasses equal parts technology, communication, and public safety. It began in the US with the Radio Act of 1912, which guaranteed use of the electromagnetic spectrum to the people, provided they demonstrated the requisite technical competence. These privileges have persisted to the present day, with a vibrant global community of radio amateurs (hams) utilizing the spectrum to tinker and experiment with wireless communications for satellites, drone control, low-power communication, radio astronomy, and so on! This course will introduce students to the history, art, and science of radio with emphasis on hands-on demonstrations and in-class projects, including soldering a low-power FM transmitter and building a directional antenna. Students will also self-study to pass an amateur radio licensing exam administered on campus, which unlocks the electromagnetic spectrum for personal, non-commercial use. Radio service for public safety is tightly woven into the cultural fabric of the Buggy tradition at Carnegie Mellon, and becoming licensed is the first step to getting involved! Topics covered include: Radio signal fundamentals; Basic electronics; Antennas; Radio wave propagation; Radio equipment; Norms and culture of amateur radio communication; Operating regulations and safety. Anyone interested in becoming a licensed amateur radio user is welcome regardless of major or prior background!

18-090 Twisted Signals: Multimedia Processing for the Arts

Fall: 10 units

[IDeATe portal course] - This course presents an overview on manipulating and synthesizing sound, video, and control signals. Signals are the raw materials used in many forms of electronic art and design - electronic music, interactive art, video art, kinetic sculpture, and more. In these fields, signals are used to represent information about sound, images, sensors, and movement. By transforming and manipulating these types of signals, we are able to create powerful new tools for digital art, multimedia applications, music, responsive environments, video and sound installation, smart products, and beyond. In this course we will study Signal Processing from a practical point-of-view, developing tools that can be easily integrated into art-making using the graphical programming environment Max (a.k.a. Max/MSP/Jitter). We will present a survey of Signal Processing techniques used in the sonic and visual arts, and will discuss the mathematical theories underlying these techniques. Students will be encouraged to combine, modify, and extend working examples of software to create original digital artworks.

18-095 Getting Started in Electronics: An Experiential Approach

Fall and Spring: 9 units

Electronics are ubiquitous and have transformed life many times over. Building circuits as a hobby has been a reliable introduction to a career in engineering for many decades, providing essential context and motivation for the mathematics and analysis techniques developed in the canonical ECE curriculum. For those with little prior knowledge of electronics, building circuits provides useful context and practical skills that lead to success in the rigorous engineering core. For those pursuing other career paths, exploring electronics develops technical literacy that will supplement and enhance their pursuits. Nowadays, the growth of maker culture has provided a wealth of tools that make electronics more accessible than ever before. This class uses an experiential learning approach to develop skills in circuit design, prototyping, and debugging. Every lecture is integrated with a hands-on laboratory experiment, punctuating each lesson with physical inquiry. The course will be based on two experiential learning texts: *Getting Started in Electronics* by Forrest Mims III, which has launched many engineering careers since the 1980s, and the modern classic *Make: Electronics* by Charles Platt. Principles of analog circuits, digital circuits, microcontrollers, and measurement equipment will be explored one experiment at a time, through twice-weekly integrated lecture/circuit builds and once-weekly self-guided builds.

18-100 Introduction to Electrical and Computer Engineering

Fall and Spring: 12 units

The goals of this freshman engineering course are: * To introduce basic concepts in electrical and computer engineering in an integrated manner; * To motivate basic concepts in the context of real applications; * To illustrate a logical way of thinking about problems and their solutions, and; * To convey the excitement of the profession. These goals are attained through analysis, construction and testing of an electromechanical system (e.g., a robot) that incorporates concepts from a broad range of areas within Electrical and Computer Engineering. Some of the specific topics that will be covered include system decomposition, ideal and real sources, Kirchhoff's Current and Voltage Laws, Ohm's Law, piecewise linear modeling of nonlinear circuit elements, Ideal Op-Amp characteristics, combinational logic circuits, Karnaugh Maps, Flip-Flops, sequential logic circuits, and finite state machines. 3 hrs. lec., 1 hr. rec., 3 hr. lab.

18-200 ECE Sophomore Seminar

Fall: 1 unit

The class comprises of a series of lectures from our own faculty and alumni, Department and University staff, and student groups. Students are required to attend each lecture. The lectures are designed to serve the following purposes: 1. Introduce to students to the faculty member's research field and the most current world advancements in engineering and technology in that area; 2. Provide students a good understanding of our curriculum structure and the courses in various areas; 3. Present correlations between the present technological developments and our courses for each course area; 4. Introduce new undergraduate courses; 5. Advertise on-campus/off-campus research opportunities for undergraduate students and explain the corresponding research projects; 6. Motivate students with positive presentations on the importance of obtaining education and gaining self-learning ability; 7. Provide basic education on learning and working ethics.

18-202 Mathematical Foundations of Electrical Engineering

Fall and Spring: 12 units

This course covers topics from engineering mathematics that serve as foundations for descriptions of electrical engineering devices and systems. It is the corequisite mathematics course for 18-220, Fundamentals of Electrical Engineering. The topics include: 1. MATLAB as a robust computational tool, used to reinforce, enrich and integrate ideas throughout the course, including software exercises and projects in combination with homework assignments; 2. Complex Analysis, including rectangular and polar representations in the complex plane with associated forms of complex arithmetic, powers, roots and complex logarithms, complex differentiation, analytic functions and Cauchy-Riemann equations, complex Taylor series, complex exponential, sinusoidal and hyperbolic functions, and Euler's formula; 3. Fourier Analysis, including orthogonality of sinusoids, trigonometric and exponential forms of Fourier series, Fourier integrals and Fourier transforms; 4. Linear, Constant-Coefficient Differential Equations, including complex exponential solutions to homogeneous equations and particular solutions with polynomial and sinusoidal driving functions described by phasors; 5. Difference Equations, with emphasis upon their relationship to differential equations, and; 6. Linear Algebra and Matrices, including matrix arithmetic, linear systems of equations and Gaussian elimination, vector spaces and rank of matrices, matrix inverses and determinants, eigenvalue problems and their relationship to systems of homogeneous differential equations.

Prerequisite: 21-122 Min. grade C

18-213 Introduction to Computer Systems

Spring and Summer: 12 units

This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE: students must achieve a C or better in order to use this course to satisfy the prerequisite for any subsequent Computer Science course.

Prerequisite: 15-122 Min. grade C

18-220 Electronic Devices and Analog Circuits

Fall and Spring: 12 units

This course covers fundamental topics that are common to a wide variety of electrical engineering devices and systems. The topics include an introduction to semiconductor devices and technology, DC circuit analysis techniques, operational amplifiers, energy storage elements, sinusoidal steady-state response, frequency domain analysis, filters, and transient response of first- and second-order systems. The laboratories allow students to use modern electronic instrumentation and to build and operate circuits that address specific concepts covered in the lectures, including semiconductor devices and sensors, layout, operational amplifiers, filters, signal detection and processing, power converters and circuit transients. 3 hrs. lec., 1 hr. rec., 3 hrs. lab.

Prerequisite: 18-100 Min. grade C

18-224 Special Topics in Chip Design

Spring

Please refer to the ECE website for descriptions of each topic: <https://courses.ece.cmu.edu/>

18-240 Structure and Design of Digital Systems

Fall and Spring: 12 units

This course introduces basic issues in design and verification of modern digital systems. Topics include: Boolean algebra, digital number systems and computer arithmetic, combinational logic design and simplification, sequential logic design and optimization, register-transfer design of digital systems, basic processor organization and instruction set issues, assembly language programming and debugging, and a hardware description language. Emphasis is on the fundamentals: the levels of abstraction and hardware description language methods that allow designers to cope with hugely complex systems, and connections to practical hardware implementation problems. Students will use computer-aided digital design software and actual hardware implementation laboratories to learn about real digital systems. 3 hr. lec., 1 hr. rec., 3 hr. lab.

Prerequisite: 18-100 Min. grade C

18-290 Signals and Systems

Fall and Spring: 12 units

This course develops the mathematical foundation and computational tools for processing continuous-time and discrete-time signals in both time and frequency domain. Key concepts and tools introduced and discussed in this class include linear time-invariant systems, impulse response, frequency response, convolution, filtering, sampling, and Fourier transform. Efficient algorithms like the fast Fourier transform (FFT) will be covered. The course provides background to a wide range of applications including speech, image, and multimedia processing, bio and medical imaging, sensor networks, communication systems, and control systems. This course serves as entry and prerequisite for any higher level course in the fields of signal processing, communications, and control.

18-300 Fundamentals of Electromagnetics

Fall: 12 units

This course introduces electromagnetic principles and describes ways in which those principles are applied in engineering devices and systems. Topics include: vector calculus as a mathematical foundation for field descriptions, Maxwell's equations in integral and differential forms with associated boundary conditions as descriptions of all electromagnetic principles, quasistatic electric fields in free space and in materials, superposition for known charge sources, conduction and polarization, resistance and capacitance, charge relaxation, analytic and numerical methods for electric field boundary value problems, quasistatic magnetic fields in free space and in materials, superposition for known current sources, magnetization, inductance, magnetic diffusion, and analytic and numerical methods for magnetic field boundary value problems. 4 hrs. lec.

Prerequisite: 18-220 Min. grade C

18-310 Fundamentals of Semiconductor Devices

Spring: 12 units

This course replaced 18311 in Spring 2005. In this course you will receive an introduction to the operation and fabrication of the most important semiconductor devices used in integrated circuit technology together with device design and layout. At the end of the course you will have a basic understanding of pn diodes, bipolar transistors, and MOSFETs as well as some light emitting and light detecting devices such as photodiodes, LEDs and solar cells. You will also receive an introduction to the fundamental concepts of semiconductor physics such as doping, electron and hole transport, and band diagrams. In the laboratory you will learn how to lay out both bipolar and MOS devices and you will design small (2-3 transistor) circuits. The laboratory portion of the course emphasizes the relation between device design and layout and circuit performance. You will also experimentally evaluate the operation of amplifier and gate circuits fabricated with discrete devices. This course will give you an excellent understanding of the operation and fabrication of the devices which is necessary for high-performance analog and digital circuit design. 3 hrs. lec. (Note: the prerequisite is typically waived for MSE students who intend to pursue the Electronic Materials Minor.)

Prerequisite: 18-220 Min. grade C

18-320 Microelectronic Circuits

Spring: 12 units

18-320 introduces students to the fundamentals of microelectronic circuits. The course will emphasize the analysis and design of basic analog and digital integrated circuits in preparation for further study in analog, digital, mixed-signal, and radio-frequency integrated circuit design. Additionally, students will learn to design and analyze microelectronic circuits using industry standard computer aided design (CAD) software. Topics to be covered include: MOSFET fabrication and layout MOSFET models for analog and digital design Analysis and design of digital CMOS logic gates Analysis and design of clocked storage elements (e.g., flip-flops, latches, memory cells) Delay optimization of digital circuits Circuit topologies for arithmetic and logical functional units Analysis and design of single-stage MOS amplifiers Frequency response characteristics of single-stage amplifiers Differential amplifiers and simple operational amplifiers Analog filters using operational amplifiers The course includes a lab component which will give students hands-on experience in the design and implementation of analog and digital circuits. Labs will employ both design using discrete, SSI, and MSI parts, as well as using CAD design tools.

Prerequisite: 18-220 Min. grade C

18-330 Introduction to Computer Security

Fall and Spring: 12 units

Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.

Prerequisite: 18-213 Min. grade C

18-334 Network Security

Spring; 12 units

Some of today's most damaging attacks on computer systems involve exploitation of network infrastructure, either as the target of attack or as a vehicle to advance attacks on end systems. This course provides an in-depth study of network attack techniques and methods to defend against them. The course will cover topics spanning five broad themes: (1) infrastructure topics such as firewalls, network intrusion detection, secure routing protocols, and recent advances such as software-defined networking; (2) network attacks such as denial of service (DoS) and distributed denial-of-service (DDoS) attacks, worm and virus propagation; (3) analysis and inference topics such as network forensics and attack economics; (4) user related topics such as authentication, anonymity and censorship resilience; and (5) new technologies related to next-generation networks, and cellular and wireless networks. Students in 18-334 will share lectures and homeworks with students in 18-731. However, 18-731 will have additional requirements not shared by 18-334, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.

Prerequisites: 15-330 Min. grade C or 18-330 Min. grade C

18-335 Secure Software Systems

Spring; 12 units

Poor software design and engineering are the root causes of most security vulnerabilities in deployed systems today. Moreover, with code mobility now commonplace and #8212;particularly in the context of web technologies and digital rights management and #8212;system designers are increasingly faced with protecting hosts from foreign software and protecting software from foreign hosts running it. This class takes a close look at software as a mechanism for attack, as a tool for protecting resources, and as a resource to be defended. Topics covered include the software design process; choices of programming languages, operating systems, databases and distributed object platforms for building secure systems; common software vulnerabilities, such as buffer overflows and race conditions; auditing software; proving properties of software; software and data watermarking; code obfuscation; tamper resistant software; and the benefits of open and closed source development. Students in 18-335 will share lectures and homeworks with students in 18-732. However, 18-732 has additional requirements not shared by 18-335, including the requirement to produce scribe notes and to practice and demonstrate the ability to read and summarize scientific papers on the topics covered by the course.

Prerequisites: (18-631 Min. grade C or 18-330 Min. grade C or 15-330 Min. grade C or 14-741 Min. grade C or 18-730 Min. grade C) and (14-513 Min. grade C or 18-213 Min. grade C or 15-513 Min. grade C or 18-613 Min. grade C or 15-213 Min. grade C)

18-340 Hardware Arithmetic for Machine Learning

Fall; 12 units

In this course, students explore the techniques for designing high-performance digital circuits for computation along with methods for evaluating their characteristics. We begin by reviewing number systems and digital arithmetic along with basic arithmetic circuits such as ripple-carry adders. From there, we move to more complex adders (carry-look-ahead, carry-skip, carry-bypass, etc.), multipliers, dividers, and floating-point units. For each circuit introduced, we will develop techniques and present theory for evaluating their functionality and speed. Other methods will be described for analyzing a circuit's power consumption, testability, silicon area requirements, correctness, and cost. In addition, we will utilize various CAD tools to evaluate the circuits described. Finally, advanced timing and clocking concepts will be investigated. For example, the notion of clock skew will be introduced and its impact on clock period for sequential circuits will be analyzed. We will also learn how to analyze and design asynchronous circuits, a class of sequential circuits that do not utilize a clock signal. Course projects focus on key arithmetic aspects of various machine learning algorithms including: K-nearest neighbors, neural networks, decision trees, and support vector machines. *Note: Although students in 18-340 and 18-640 will share lectures, labs, and recitations, students in 18-340 and 18-640 will receive different homework assignments, design projects, and exams. In some cases 18-640 students will also have different or additional lab sessions. The homework assignments, design projects, and exams that are given to the students registered for 18-640 will be more challenging than those given to the students registered for 18-340 in that they will have more complex designs, involve additional theoretical analysis, and have more stringent specifications (e.g., in area, power, performance, and robustness).

Prerequisite: 18-240 Min. grade C

18-341 Logic Design and Verification

Fall; 12 units

This course is a second level logic design course, studying the techniques of designing at the register-transfer and logic levels of complex digital systems using modern modeling, simulation, synthesis, and verification tools.

Topics include register-transfer level systems (i.e., finite state machines and data paths), bus and communication system interfacing (such as a simplified USB interface), discrete-event simulation, testbench organization, assertion-based verification and functional coverage. Design examples will be drawn from bus and communication interfaces, and computation systems, emphasizing how these systems are designed and how their functionality can be verified. A modern hardware description language, such as SystemVerilog, will serve as the basis for uniting these topics. Quizzes, homeworks and design projects will serve to exercise these topics.

Prerequisite: 18-240 Min. grade C

18-344 Computer Systems and the Hardware-Software Interface

Fall; 12 units

This course covers the design and implementation of computer systems from the perspective of the hardware software interface. The purpose of this course is for students to understand the relationship between the operating system, software, and computer architecture. Students that complete the course will have learned operating system fundamentals, computer architecture fundamentals, compilation to hardware abstractions, and how software actually executes from the perspective of the hardware/software boundary. The course will focus especially on understanding the relationships between software and hardware, and how those relationships influence the design of a computer system's software and hardware. The course will convey these topics through a series of practical, implementation-oriented lab assignments.

Prerequisites: 18-213 Min. grade C and 18-240 Min. grade C

18-349 Introduction to Embedded Systems

Fall and Spring; 12 units

This practical, hands-on course introduces the various building blocks and underlying scientific and engineering principles behind embedded real-time systems. The course covers the integrated hardware and software aspects of embedded processor architectures, along with advanced topics such as real-time, resource/device and memory management. Students can expect to learn how to program with the embedded architecture that is ubiquitous in cell-phones, portable gaming devices, robots, PDAs, etc. Students will then go on to learn and apply real-time principles that are used to drive critical embedded systems like automobiles, avionics, medical equipment, the Mars rover, etc. Topics covered include embedded architectures (building up to modern 16/32/64-bit embedded processors); interaction with devices (buses, memory architectures, memory management, device drivers); concurrency (software and hardware interrupts, timers); real-time principles (multi-tasking, scheduling, synchronization); implementation trade-offs, profiling and code optimization (for performance and memory); embedded software (exception handling, loading, mode-switching, programming embedded systems). Through a series of laboratory exercises with state-of-the-art embedded processors and industry-strength development tools, students will acquire skills in the design/implementation/debugging of core embedded real-time functionality.

Prerequisites: 18-213 Min. grade C and 18-240 Min. grade C

18-351 Full Stack Skills for Engineers

Fall; 6 units

This course will introduce the principles, concepts, technologies, and practices of full-stack software development for creating end-to-end web applications using a classical client-server architecture and the model-view-controller pattern. Students will acquire basic front-end and back-end skills and learn how to apply modern development practices in the context of an individual hands-on project using the plain web stack for the front-end, TypeScript and a NoSQL database layer for the back-end, and other common libraries, light-weight frameworks, and tools as adjuncts. They will practice how to version-control the codebase, manage a small project, transform requirements expressed as user stories into working software in an incremental manner, maintain code quality, build their application on an integration server, and deploy it on the cloud. To enroll in this course, students must already be proficient in coding using multiple programming languages and familiar with the basics of algorithms, data structures, databases, and software design principles, including object-orientation. Each student will need their own laptop computer to use in the course.

Prerequisites: 18-213 Min. grade C or 15-213 Min. grade C or 17-214 Min. grade C

18-352 Software Engineering Essentials

Spring: 12 units

In this course, students will learn about and apply software engineering paradigms that have shaped the software industry over the past few decades. They will be exposed to fundamental disciplines of software engineering as well as central engineering practices that crosscut system, project, and user perspectives. They will iteratively analyze and implement user requirements in the presence of a customer proxy, and architect, design, implement, integrate, test, and deploy an evolving solution that balances multiple engineering and user constraints. The course is organized around a semester-long team project with frequent milestones, deliverables, demonstrations, and assessments. Newly introduced course topics are immediately applied to the team project. The team project starts right away and relies on several software technologies, tools, and stacks: prior knowledge of these elements is therefore paramount. To enroll, students must have substantial programming experience and be already familiar with these elements. This course can replace 18652 to satisfy a core requirement of ECEs MS-SE program.

Prerequisites: 18-351 Min. grade C or 17-437

18-358 Special Topics in Communications

Spring: 6 units

Please go to the ECE website to view "Special Topics in Communications" course descriptions.

Course Website: <https://courses.ece.cmu.edu/>**18-370 Fundamentals of Control**

Fall: 12 units

This junior/senior-level undergraduate course introduces the fundamental principles and methodologies of classical feedback control of linear systems and its applications. Emphasis is on understanding physical principles in feedback systems, practical problem formulation and the analysis and synthesis of feedback control systems using frequency and time domain techniques. The covered material provides a foundation for further studies toward careers in motion control, automation, control electronics, robotics, systems science and engineering. The practical knowledge in this course represents necessary tools to design a broad variety of systems such as robots, servo and tracking systems, feedback circuits, phase-locked loops, and microelectromechanical systems. Topics include analytical, graphical and computer-aided techniques (MATLAB/Simulink) for analyzing, designing and realizing of feedback control systems; Laplace transforms and associated transfer function modeling; root-locus and frequency response (Bode plot) design; pole-zero synthesis techniques; analysis of trade-offs in performance: stability, transient response, steady-state error, disturbance rejection, and robustness; design and implementation of PID, lead-lag, and loop shaping compensators. If time permits, the course will include a cursory introduction to state space modeling, systems with delay and computer control systems.

Prerequisites: 18-290 Min. grade C or 24-352 Min. grade C or 18-220 Min. grade C

18-372 Fundamental Electrical Power Systems

Fall: 12 units

This course introduces the fundamentals in electric energy systems which will enable you to understand current issues and challenges in electric power systems ("smart grid") and what it takes for you to have a reliable electric power supply at your house. First, the general structure of an electric power system (current and future trends) will be introduced. This includes electric power plants (renewable and non-renewable); transmission and distribution; and consumers. Then, electric power is addressed from a mathematical point of view. The mathematical formulae for AC power and models for the above mentioned elements are derived which will enable you to calculate how much power is flowing over which lines on its way from the power plant to the consumer. Maintaining the balance between generation and consumption is important to avoid catastrophic blackout events. Hence, the notion of stability and available control concepts will be introduced.

Prerequisites: 18-202 Min. grade C and 18-220 Min. grade C

18-390 ECE CO-OP

Fall and Spring

The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended period of exposure with a company. To participate, students must work with their academic advisor to complete an ECE Co-op Approval form and submit for approval. Students must possess at least junior status and have an overall grade point average of 3.0 or above. All co-ops must be approximately 8 months in uninterrupted length. If the co-op is approved, the ECE Undergraduate Studies Office will add the course to the student's schedule. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ECE Undergraduate Office. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

18-399 Special Topics in Signal Processing

Intermittent: 3 units

Please refer to the ECE website to view "Special Topics in Signal Processing" course descriptions. <http://www.ece.cmu.edu/courses/index.html> (<http://www.ece.cmu.edu/courses/>)

18-401 Electromechanics

12 units

This course provides a broadly based introduction to interactions between mechanical media and electromagnetic fields. Attention is focused on the electromechanical dynamics of lumped-parameter systems, wherein electrical and mechanical subsystems may be modeled in terms of discrete elements. Interactions of quasistatic electric and magnetic fields with moving media are described and exemplified. Unifying examples are drawn from a wide range of technological applications, including energy conversion in synchronous, induction, and commutator rotating machines, electromechanical relays, a capacitor microphone and speaker, and a feedback-controlled magnetic levitation system. 4.5 hrs. rec.

Prerequisite: 18-300

18-402 Applied Electrodynamics

Spring: 12 units

This course builds upon the electric and magnetic field foundations established in 18-300 to describe phenomena and devices where electromagnetic waves are a central issue. Topics include: review of Maxwell's equations, propagation of uniform plane waves in lossless and lossy media, energy conservation as described by the Poynting Theorem, reflection and transmission with normal and oblique incidence upon boundaries, sinusoidal steady state and transients on 2-conductor transmission lines, modal descriptions of waveguides, radiation and antennas. 4 hrs. lec.

Prerequisite: 18-300

18-403 Microfabrication Methods and Technology

Fall: 12 units

This course is a laboratory-based introduction to the theory and practice of microfabrication. Lectures and laboratory sessions cover fundamental processing techniques such as photo-mask creation, lithographic patterning, thin film vacuum deposition processes, wet-chemical and dry-etching processes. This is primarily a hands-on laboratory course which brings students into the microfabrication facility and device testing laboratories. Students will fabricate electronic and opto-electronic devices such the metal-oxide-semiconductor (MOS) capacitor, the Schottky diode, the MOS transistor, the solar cell, and the light-emitting diode. An understanding of the operation of these building block devices will be gained by performing measurements of their electrical and opto-electronic characteristics. Emphasis is placed on understanding the interrelationships between the materials properties, processing, device structure, and the electrical and optical behavior of the devices. The course is intended to provide a background for a deeper appreciation of solid state electronic devices and integrated circuits. 2 lecture periods per week and a minimum of 4 laboratory hours.

Prerequisite: 18-310

18-411 Computational Techniques for Data Science and Engineering

Spring; 12 units

This course covers mathematical techniques that permit formulation of equations that often emerge out of engineering and science problems or experimental data in a manner that makes them computationally tractable for numerical solutions and analysis. Numerical approaches to solving engineering or science equations allow one to perform computer simulations that can often answer key questions without actual experimentation (which can be costly and time-consuming). The course is divided into two major modules. The first develops foundational background in modeling, computers, error analysis, linear algebra, regression, and curve fitting. To illustrate applications of the main concepts of the first module, we discuss how to use them in machine learning, specifically in deep learning. Students carry out a deep learning project of their choosing to sharpen their comprehension of both the mathematics behind deep learning, and the machine learning algorithms that enable the most common applications of deep learning. The second module builds on the first to develop skills in numerical differentiation and integration and continues with techniques for computational solution of ordinary and partial differential equations that arise from physical or engineering problems. Students learn how to set up these equations in a manner that allows numerical solutions to be obtained by either writing simple computer code or macros that interface with open-source Python code or commercially available software packages such as MATLAB or Mathematica.

Prerequisites: (15-110 Min. grade C or 15-112) and 21-120

18-416 Nano-Bio-Photonics

Spring; 12 units

Light can penetrate biological tissues non-invasively. Most of the available bio-optic tools are bulky. With the advent of novel nanotechnologies, building on-chip integrated photonic devices for applications such as sensing, imaging, neural stimulation, and monitoring is now a possibility. These devices can be embedded in portable electronic devices such as cell phones for point of care diagnostics. This course is designed to convey the concepts of nano-bio-photonics in a practical way to prepare students to engage in emerging photonic technologies. The course starts with a review of electrodynamics of lightwaves. The appropriate choice of wavelength and material platform is the next topic. Then optical waveguides and resonators are discussed. Resonance-based sensing is introduced followed by a discussion of the Figure of Merits (FOMs) used to design on-chip sensors. Silicon photonics is introduced as an example of a CMOS-compatible platform. On-chip spectroscopy is the next topic. The second part covers nano-plasmonics for bio-detection and therapy. The design methods are discussed, followed by an overview of nanofabrication and chemical synthesis, and then a discussion of applications. The last part of this course will be dedicated to a review of recent applications such as Optogenetic neural stimulation, Calcium imaging, Cancer Imaging and Therapy. Senior or graduate standing required. This course is cross-listed with 18616. Although students in 18-616 and 18-416 will share the same lectures and recitations, students in 18-616 will receive distinct course projects. Students in 18-416 and 18-616 will be graded on separate curves. Prerequisite: 18-300 Min. grade C

18-421 Analog Integrated Circuit Design

Spring; 12 units

Some form of analog circuit design is a critical step in the creation of every modern IC. First and foremost, analog circuits act as the interface between digital systems and the real world. They act to amplify and filter analog signals, and to convert signals from analog to digital and back again. In addition, high performance digital cell design (either high speed or low power) also invokes significant analog circuit design issues. The goal of this course is to teach students some of the methods used in the design and analysis of analog integrated circuits, to illustrate how one approaches design problems in general, and to expose students to a broad cross-section of important analog circuit topologies. The course will focus on learning design through carrying out design projects. Design and implementation details of wide-band amplifiers, operational amplifiers, filters and basic data converters will be covered. Example topics to be covered include transistor large- and small-signal device models, small-signal characteristics of transistor-based amplifiers, large-signal amplifier characteristics and nonidealities, operational amplifier design, basic feedback amplifier stability analysis and compensation, and comparator design. The course will focus primarily on analog CMOS, but some aspects of BJT design will be discussed. 18-290 and 18-320 or equivalent background material with permission of the instructor. Although students in 18-623 will share Lectures and Recitations with students in 18-421, students in 18-623 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18-421 and will be graded on a separate curve from students taking 18-421.

Prerequisites: 18-320 Min. grade C and 18-290 Min. grade C

18-422 Digital Integrated Circuit Design

Fall; 12 units

This course covers the design and implementation of digital circuits in a modern VLSI process technology. Topics will include logic gate design, functional unit design, latch/flip-flop design, system clocking, memory design, clock distribution, power supply distribution, design for test, and design for manufacturing. The lab component of the course will focus on using modern computer aided design (CAD) software to design, simulate, and lay out digital circuits. The final project for the course involves the design and implementation to the layout level of a small microprocessor. 18-240 and 18-320 or equivalent background material with permission of the instructor. Although students in 18-422 and 18-622 will share lectures, labs, and recitations, students in 18-422 and 18-622 will receive different homework assignments, design projects, and exams, and in some cases 18-622 students will also have different or additional lab sessions. Prerequisites: 18-240 Min. grade C and 18-320 Min. grade C

18-435 Foundations of Blockchains

Fall; 12 units

In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is cross-listed with 18635. ECE graduate students will be prioritized for 18635, and ECE undergraduate students will be prioritized for 18435. Although students in 18435 will share lectures with students in 18635, students in 18435 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18635. Specifically, the homework assignments, programming projects, and exams that are given to the 18635 students will be more challenging than those given to the 18435 students.

Prerequisites: 18-334 Min. grade C or 18-335 Min. grade C or 18-465 Min. grade C or 18-733 Min. grade C or (18-202 Min. grade C and 18-213 Min. grade C) or (18-202 Min. grade C and 15-513 Min. grade C) or (18-202 Min. grade C and 18-613 Min. grade C) or (18-202 Min. grade C and 14-513 Min. grade C)

18-441 Computer Networks

Fall; 12 units

The Internet has transformed our everyday lives, bringing people closer together and powering multi-billion dollar industries. The mobile revolution has brought Internet connectivity to the last-mile, connecting billions of users worldwide. But how does the Internet work? What do oft repeated acronyms like "LTE", "TCP", "WWW" or a "HTTP" actually mean and how do they work? This course introduces fundamental concepts of computer networks that form the building blocks of the Internet. We trace the journey of messages sent over the Internet from bits in a computer or phone to packets and eventually signals over the air or wires. We describe concepts that are common to and differentiate traditional wired computer networks from wireless and mobile networks. Finally, we build up to exciting new trends in computer networks such as the Internet of Things, 5-G and software defined networking. Topics include: physical layer and coding (CDMA, OFDM, etc.); data link protocol; flow control, congestion control, routing; local area networks (Ethernet, Wi-Fi, etc.); transport layer; and introduction to cellular (LTE) and 5-G networks. A final project asks you to build a HTTP video server of your own. This course is cross-listed with 18-741 - both editions will share Lectures and Recitations. However, students in the two courses will receive different exams and will have a different project. The students in the two versions of the course will be graded on a separate curve.

Prerequisites: (36-225 Min. grade C or 36-226 Min. grade C or 36-212 Min. grade C or 36-217 Min. grade C) and 18-213 Min. grade C

18-447 Introduction to Computer Architecture

Spring: 12 units

Computer architecture is the science and art of selecting and interconnecting hardware components to create a computer that meets functional, performance and cost goals. This course introduces the basic hardware structure of a modern programmable computer, including the basic laws underlying performance evaluation. We will learn, for example, how to design the control and data path hardware for a MIPS-like processor, how to make machine instructions execute simultaneously through pipelining and simple superscalar execution, and how to design fast memory and storage systems. The principles presented in the lecture are reinforced in the laboratory through the design and simulation of a register transfer (RT) implementation of a MIPS-like pipelined superscalar in Verilog. Learning to design programmable systems requires that you already have the knowledge of building RT systems, the knowledge of the behavior storage hierarchies (e.g., cache memories) and virtual memory, and the knowledge of assembly language programming.

Prerequisites: 18-240 Min. grade C and (18-213 Min. grade C or 15-213 Min. grade C) and (18-349 Min. grade C or 18-320 Min. grade C or 18-340 Min. grade C or 18-330 Min. grade C or 18-341 Min. grade C or 18-344 Min. grade C)

18-448 Special Topics in Embedded Systems

Intermittent: 12 units

Please refer to the ECE website for descriptions of each topic: <https://courses.ece.cmu.edu/>

18-452 Wireless Networking and Applications

Spring: 12 units

This course introduces fundamental concepts of wireless networks. The design of wireless networks is influenced heavily by how signals travel through space, so the course starts with an introduction to the wireless physical layer, presented in a way that is accessible to a broad range of students. The focus of the course is on wireless MAC concepts including CSMA, TDMA/FDMA, and CDMA. It also covers a broad range of wireless networking standards, and reviews important wireless network application areas (e.g., sensor networks, vehicular) and other applications of wireless technologies (e.g., GPS, RFID, sensing, etc.). Finally, we will touch on public policy issues, e.g., as related to spectrum use. The course will specifically cover: Wireless networking challenges Wireless communication overview Wireless MAC concepts Overview of cellular standards and LTE Overview of wireless MAC protocols WiFi, bluetooth and personal area networks, etc. Wireless in today's Internet: TCP over wireless, mobility, security, etc. Advanced topics, e.g., mesh and vehicular networks, sensor networks, DTNs, localization, sensing, etc. Although students in 18-750 will share Lectures and Recitations with students in 18-452, they will receive distinct homework assignments and exams from students in 18-452. The main project will also be different. The students in the two version of the course will also be graded on a separate curve.

Prerequisites: 15-213 Min. grade C or 18-613 Min. grade C or 18-213 Min. grade C

18-453 Introduction to XR Systems

Fall: 12 units

Digitization of reality is at the cusp of widespread adoption; it also embodies a unique convergence of techniques that span the gamut of electrical and computer engineering. This course introduces students to augmented/virtual/mixed reality systems, or what is broadly referred to as extended reality (XR). The course covers hardware and software topics central to XR systems, namely, content capture, streaming, and display, looking at both commercial and research-grade systems. A course project will allow students to experience and innovate in this space.

Prerequisites: 18-213 Min. grade C or 18-290 Min. grade C

18-460 Optimization

Spring: 12 units

Many design problems in engineering (e.g., machine learning, finance, circuit design, etc.) involve minimizing (or maximizing) a cost (or reward) function. However, solving these problems analytically is often challenging. Optimization is the study of algorithms and theory for numerically solving such problems, and it underpins many of the technologies we use today. This course is an introduction to optimization. Students will: (1) learn about common classes of optimization problems, (2) study (and implement) algorithms for solving them, and (3) gain hands-on experience with standard optimization tools. We will focus on convex optimization problems, but will also discuss the growing role of non-convex optimization, as well as some more general numerical methods. The course will emphasize connections to real-world applications including machine learning, networking, and finance. The course will involve lectures, homework, exams, and a project. This course is crosslisted with 18660. Although students in 18460 will share lectures with students in 18660, students in 18460 will receive distinct homework assignments, distinct design problems, and distinct exams from the ones given to students in 18660. Specifically, the homework assignments, design problems and exams that are given to the 18660 students will be more challenging than those given to the 18460 students. Prerequisites: (21-254 Min. grade C or 21-259 Min. grade C or 21-260 Min. grade C or 18-202 Min. grade C) and (36-217 Min. grade C or 21-325 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 36-219 Min. grade C) and 21-241 Min. grade C

18-461 Introduction to Machine Learning for Engineers

Fall: 12 units

This course provides an introduction to machine learning with a special focus on engineering applications. The course starts with a mathematical background required for machine learning and covers approaches for supervised learning (linear models, kernel methods, decision trees, neural networks) and unsupervised learning (clustering, dimensionality reduction), as well as theoretical foundations of machine learning (learning theory, optimization). Evaluation will consist of mathematical problem sets and programming projects targeting real-world engineering applications. This course provides an introduction to machine learning with a special focus on engineering applications. The course starts with a mathematical background required for machine learning and covers approaches for supervised learning (linear models, kernel methods, decision trees, neural networks) and unsupervised learning (clustering, dimensionality reduction), as well as theoretical foundations of machine learning (learning theory, optimization). Evaluation will consist of mathematical problem sets and programming projects targeting real-world engineering applications. This course is crosslisted with 18661. ECE graduate students will be prioritized for 18661, and ECE undergraduate students will be prioritized for 18461. Although students in 18461 will share lectures with students in 18661, students in 18461 will receive distinct homework assignments, distinct programming projects, and distinct exams from the ones given to students in 18661. Specifically, the homework assignments, programming projects, and exams that are given to the 18661 students will be more challenging than those given to the 18461 students.

Prerequisites: 18-202 Min. grade C and 21-127 Min. grade C and 15-122 Min. grade C and (36-225 Min. grade C or 36-218 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C)

18-462 Principles and Engineering Applications of AI

Spring: 12 units

This is a first-year graduate course in Principles and Engineering Applications of AI. The course will review the basic principles of AI. Some of the specific topics that will be covered are the following: 1) Intelligent Agents; 2) Single-Agents and Multi-Agent Systems (MAS); 3) Uncertain Knowledge and Reasoning (Probabilistic Reasoning and Probabilistic Reasoning over Time, Bayesian Networks, Dynamic Bayesian Networks, Hidden Markov Models, Kalman Filters, MCMC algorithms, etc.); 4) Learning; 5) Communicating, Perceiving, and Acting; 6) Robotics. The course will involve completing a set of challenging engineering applications of AI that will include: Medical applications, Video Games, Autonomous driving, Autonomous Robots, Finance and Economics, Military, Art, Advertising. Students should have a good background in basic probability theory, maturity in mathematical topics, and good programming skills. For seniors who would like to take the course but do not have the necessary prerequisites, instructor's permission will be required. Although students in 18462 will share lectures with students in 18662, students in 18462 will receive distinct homework assignments, distinct projects, and distinct exams from the ones given to students in 18662. Specifically, the homework assignments, projects, and exams that are given to the 18662 students will be more challenging than those given to the 18462 students.

Prerequisites: 18-751 Min. grade B or 36-218 Min. grade B or 36-217 Min. grade B or 36-219 Min. grade B

18-464 ULSI Technology Status and Roadmap for System on Chips and System in Package

Fall and Spring: 12 units

This course will provide the necessary background for the state-of-the-art technologies utilized by the leading edge products covering full spectrum of market drivers from mobile platforms, microprocessors, game chips to the highest performance systems for enterprise solutions computing. We will present all key components of such systems, i.e., logic, analog/RF and embedded memories. Then we present the technology roadmap for the upcoming generations in terms of device architecture options for logic devices (FinFET, Nanowire and Tunnel FET) and memories (Phase Change Memory, Resistive RAM and Magnetic RAM/Spin-Transfer Torque RAM) from the device level all the way to the system level specifications. The last part of the class will be devoted to the system integration issues, namely 3-dimensional integration approaches. This course is designed for MS and PhD students from diverse areas: System/Hardware Design, Circuits and Devices/Nanofabrication and is aimed at bridging the gap among these areas.

Prerequisites: 18-422 or 18-320

18-465 Advanced Probability & Statistics for Engineers

Spring: 12 units

This course will help masters and undergraduate students to obtain the background necessary for excelling in courses and careers in machine learning, artificial intelligence, and related fields. We will cover basic concepts of probability prerequisite to understanding the material typically taught in a ML course. We will also cover slightly more advanced topics including Markov Chains, hypothesis testing, and maximum-likelihood estimation. The remaining part of the semester will be devoted to introducing machine learning concepts such as supervised/unsupervised learning, model identification, clustering, expectation maximization, etc. Students should be familiar with basic calculus, linear algebra. Although students in 18465 will share lectures with students in 18665, students in 18465 will receive distinct homework assignments, distinct projects, and distinct exams from the ones given to students in 18665. Specifically, the homework assignments, projects, and exams that are given to the 18665 students will be more challenging than those given to the 18465 students.

18-469 Special Topics in Integrated Systems Technology

Fall: 12 units

Please refer to the ECE website for topic descriptions.

Course Website: <https://courses.ece.cmu.edu/>**18-474 Embedded Control Systems**

Spring: 12 units

This course introduces principles for design of embedded controllers. In applications ranging from airplanes, to automobiles, to manufacturing systems, embedded computers now close feedback loops that were previously closed by mechanical devices or by humans in the loop. This course emphasizes practical insight into the tools for modeling and simulating these dynamic physical systems, and methods for designing the real-time software for embedded computers to control them. Lectures cover relevant theory and background from real-time systems and control engineering, including event-based and clock-based sampling, switching control, PWM (pulse-width modulation), PID (proportional-integral-derivative) design, state-variable feedback, state estimation, and methods for setpoint control and trajectory tracking. Basic embedded computing, sensor, and actuator technologies are reviewed, including microcontrollers, DC motors and optical encoders. In the laboratory, students use commercial tools for simulation and automatic code generation to design and implement embedded control system experiments. 3 hrs. lecture, 3 hrs. lab.

Prerequisites: (18-213 or 15-213) and (18-290 or 18-396 or 18-370)

18-482 Telecommunications Technology and Policy for the Internet Age

Spring: 12 units

Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to telecommunications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.

Prerequisite: 73-102

18-487 Introduction to Computer Security

Fall: 12 units

Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems. Anti-requisites: 18-631 and 18-730

Prerequisite: 18-213

18-490 Electroacoustics

Fall: 12 units

This course provides an introduction to physical, engineering, and architectural acoustics. The course begins with a review of the wave equation and some of its solutions that are relevant to the propagation of sound from planar and spherical sources, and from arrays of simple sources. Lumped-parameter electrical circuit analogies are developed to describe mechanical and acoustical systems, leading to a discussion of the constraints and tradeoffs involved in the design of loudspeakers, microphones, and other transducers. The characteristics of sound in regular and irregular enclosures will be developed and discussed in the context of the acoustical design for rooms and auditoriums. The interaction of sound and man is also discussed, with introductory lectures on auditory perception and the acoustics of speech production, with applications in the areas of efficient perceptually-based coding of music and speech, and virtual acoustical environments.

Prerequisites: 18-290 Min. grade C and 18-220 Min. grade C

18-491 Digital Signal Processing

Fall: 12 units

This course addresses the mathematics, implementation, design and application of the digital signal processing algorithms widely used in areas such as multimedia telecommunications and speech and image processing. Topics include discrete-time signals and systems, discrete-time Fourier transforms and Z-transforms, discrete Fourier transforms and fast Fourier transforms, digital filter design and implementation, and multi-rate signal processing. The course will include introductory discussions of 2-dimensional signal processing, linear prediction, adaptive filtering, and selected application areas. Classroom lectures are supplemented with implementation exercises using MATLAB. Students in 18491 and 18691 will share the same lectures and recitations. Nevertheless, students receiving credit for 18691 will be required to complete an additional capstone project at the end of the semester. Students in 18691 may have additional homework problems on a weekly basis.

Prerequisite: 18-290 Min. grade C

18-495 Speech Processing

Fall: 12 units

Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, speech synthesis systems and integrate them to create a speech interface. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology. Prerequisite: 15-211 Min. grade B

18-499 Summer Internship

All Semesters

The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. ECE students interested in registering their internship for course credit on their transcript may request to be enrolled in this course. The ECE Undergraduate Office will add the course to the student's schedule, and the student will be assessed tuition for 3 units. This process should be used by international students interested in Curricular Practical Training (CPT) or by any other engineering undergraduate wishing to have their internship experience reflected on their official University transcript. International students should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website.

18-500 ECE Design Experience

Fall and Spring: 12 units

The ECE Design Experience is a capstone design course that serves to introduce students to broad-based, practical engineering design and applications through an open-ended design problem. Students will work with a team on a project of their choosing (subject to instructor approval) throughout the semester culminating with a final project presentation, report, and public demonstration. The projects will need to encompass a minimum of two ECE areas. Throughout the semester, teams will need to give both written and oral project proposals and periodic performance updates. Team-building experiences designed to educate students on group dynamics, resource management, deadline planning, Big-picture implications of engineering applications: societal, human, ethical, and long-term impact will be explored. Please note that the full prerequisite list of "All ECE Core Courses plus any two 18-xxx ECE Area Courses" is too long to be put into the registration system. As a result ALL students will be waitlisted for 18-500. Students will be registered once it has been confirmed they have completed the prerequisites, after final grades for the current semester.

18-540 Rapid Prototyping of Computer Systems

Spring: 12 units

This is a project-oriented course which will deal with all four aspects of project development; the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class, in conjunction with the instructors, will develop specifications for a mobile computer to assist in inspection and maintenance. The application will be partitioned between human computer interaction, electronics, industrial design, mechanical, and software components. The class will be divided into groups to specify, design, and implement the various subsystems. The goal is to produce a working hardware/software prototype of the system and to evaluate the user acceptability of the system. We will also monitor our progress in the design process by capturing our design escapes (errors) with the Orthogonal Defect Classification (ODC). Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided design tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. Senior standing is required. This course is crosslisted as 18745

Prerequisites: (18-491 Min. grade C or 18-320 Min. grade C or 18-370 Min. grade C) and (18-340 Min. grade C or 18-341 Min. grade C or 18-349 Min. grade C) and 18-213 and 18-220 and 18-240 and 18-290

18-555 Entrepreneurial Engineering Project

Fall and Spring: 12 units

In this course, Undergraduate (18555) and MS (18655) students participate in projects to develop exploratory designs of systems for a wide range of applications. Each project is unique to a team of students who will typically be paired with an external investment partner. All the projects will be designed, developed, and led by students. Entry into the course is by invitation from the faculty instructor (typically advised by the external investment partners). Student teams will be invited based on the alignment of their skill sets and experience with a set of posted projects. Teams may also be invited based on a student-initiated pitch of their own ideas and its alignment with external investor interest. Students interested in the course can indicate their interest, qualifications, and project ideas via instructions from departmental advisors or the course instructor. Grades will be assigned by the faculty instructor based on novelty and creativity of the project, engineering process, and weekly progress, not the ultimate success or failure of the project idea or originally proposed solution. Following completion of the course, the external investment partners and students can independently explore subsequent seed funding and/or licensing of successful ideas and projects. Please note that the prerequisite list of "Any 2 18-xxx ECE Area Courses" is too long to be put into the registration system. Students whose applications are selected will be registered once it has been confirmed they have completed the prerequisites, after final grades for the current semester.

18-570 Summer Undergraduate Student-Directed Projects

Summer

Student-directed projects may be available in the summer semester only, allowing a student to explore a topic of their choosing. Students are responsible for pursuing such an option with a faculty member. Enrollment in 18570 precludes earning pay or research credit and requires completing a directed study agreement.

18-578 Mechatronic Design

Spring: 12 units

Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. Because of the emphasis upon integration, this course will center around system integration in which small teams of students will configure, design, and implement a succession of mechatronic subsystems, leading to a main project. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, electronics, and control components. Class lectures will cover topics intended to complement the laboratory work, including mechanisms, actuators, motor drives, sensors and electronic interfaces, microcontroller hardware and programming and basic controls. During the first week of class, each student will be asked to complete a questionnaire about their technical background. The class will then be divided into multi-disciplinary teams of three students. During the first half of the class, lab assignments will be made every 1-2 weeks to construct useful subsystems based on material learned in lecture. The lab assignments are geared to build to the main project. This course is cross-listed as 16-778 and 24-778. Students in other departments may take the course upon availability of slots with permission of instructor. Non ECE students may take the course upon availability of slots with permission of the instructor.

Prerequisites: (18-320 and 18-348) or (15-313 and 18-348) or (18-370 and 18-348) or (18-349 and 18-370) or (18-349 and 15-313) or (18-320 and 18-349) or (18-320 and 18-370)

18-580 Undergraduate Projects

All Semesters

The Department of Electrical and Computer Engineering at Carnegie Mellon considers experiential learning opportunities to be important educational options for its undergraduate students. One such option is conducting undergraduate research with a faculty member. Students do not need to officially register for undergraduate research unless they want it listed on their official transcripts. An ECE student who is involved in a research project and is interested in registering this undergraduate research for course credit on the official transcript may request to be enrolled in this course. To do this, the student should first complete the online undergraduate research form available on the ECE undergraduate student page. Once the form has been submitted and approved by the faculty member with whom the student is conducting the research, the ECE Undergraduate Office will add the course to the student's schedule. Typically, credit is granted according to one hour of research per week is equal to one unit of credit.

18-591 ECE Teaching Assistant Experience

Fall and Spring

Students must complete the online Teaching Assistant application to be considered for a position. TAs can expect to work 10-12 hours per week on average. See <https://www.ece.cmu.edu/insider/teaching-opportunities.html> for further information about applying for a Teaching Assistant position.

18-614 Microelectromechanical Systems

Fall: 12 units

This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments. 4 hrs. lec.

Prerequisites: 18-300 Min. grade C or 18-310 Min. grade C or 24-351 Min. grade C or 18-320 Min. grade C

18-681 Power Electronics

Fall: 12 units

This course is aimed at developing Power Electronics expertise in Masters level students to develop knowledge and skills necessary for the formation of a power electronics engineer. Considerations of static and dynamic characteristics of power semiconductor devices including thermal management are followed by the analysis and design of principal types of power converters. Key applications are also considered so that the course provides a broad knowledge and skills in the field of power electronics in wide ranging applications. Assessment is based on assignments and examinations. It is assumed that students will have an understanding of electrical and amp; electronic principles, power systems, and electrical machines. Content includes: Power Semiconductor Devices Static and Dynamic Characteristics; Application of semiconductor devices and components in the medium to high voltage environment: Series and parallel operation, damping components; Spread of device characteristics, Thermal Management; Naturally commutated converters: Single phase and three phase up to 12 pulse, analysis and operation; Effect of supply side reactance; Grid applications; DC-DC Converters and energy storage: step up and step down operation, application to electric vehicles, battery management and PV systems; Self-commutated converters; Pulsewidth modulation; Multilevel converters; HVDC light; Voltage source converter based HVDC; AC to AC Converters: grid applications.

18-866 Off-Grid Electricity Systems

Spring: 6 units

Over one billion people in the world still lack access to electricity, many of them out of reach of the electricity grid in the near term. This course will explore the technologies and architectures used to provide electricity services in off-grid regions of the developing world. Basic system design principles will be discussed and applied. Students will use energy modeling software to characterize the performance and economic viability of off-grid electricity systems. In addition to studying off-grid technologies, the course will also explore the context in which these systems are deployed and their role in enabling development.

18-867 Applied Smart Grid Telecoms

Spring: 6 units

This course examines applications of standards for communications protocols in smart grids, covering relevant standards such as IEC61850 and DNP3. Participants will complete assignments based on real world examples that explore the implementation and limitations of smart grids telecommunications. Appropriate for communications engineers wanting to understand the power grid, and power engineers wanting to develop their applied knowledge of communications.

Department of Engineering and Public Policy

Peter Adams, Department Head

Deanna H. Matthews, Associate Department Head for Undergraduate Affairs

Location: Wean Hall 5215
www.cmu.edu/epp (<http://www.cmu.edu/epp/>)

The Department of Engineering and Public Policy (EPP) is a unique department that works on problems at the interface between technology and society. Society is largely responsible for setting the goals and framing the problems that engineers and scientists work on. However, technologies designed by engineers and scientists profoundly change the societies in which they operate. Technology has enabled a healthier, richer, and more productive society. At the same time, technology has contributed to the creation of many of the more serious problems our society faces. In order to do their jobs responsibly and well in today's world, engineers and scientists must develop an understanding of the interface between technology and society and a command of the skills necessary to work at that interface. Our undergraduate programs aim to educate young scholars to be interdisciplinary problem solvers.

The undergraduate degree programs of the Department of Engineering and Public Policy (EPP) have been designed to allow undergraduate students at Carnegie Mellon University to add this important interdisciplinary dimension to their traditional engineering or science education. Our additional major graduates, for the most part, will enter traditional engineering or science careers, but will carry with them a set of insights and skills that will help them to better deal with issues in technology and policy, and better exercise their ethical and social obligations as practicing professionals. Our program has a long history of 50+ years producing graduates with these critical skills, with alumni serving in all areas of industry and government.

Overview of Our Undergraduate Programs

The undergraduate additional major programs in EPP combine the strong foundation in mathematics and physical sciences, and the development of engineering or science skills with a rigorous preparation in the analysis of social and political problems. The curriculum includes subject matter which is not part of traditional technical or social science curricula, but which contains elements of each. Students complete courses in four core areas: economics, statistics, decision-making, and communication. Breadth is achieved through EPP Technology-Policy elective courses. Finally, students apply their skills in a project preparatory course and two interdisciplinary problem-solving projects. Problem areas for these projects are chosen from local, state, and national situations, and include such topics as climate change, energy systems, technological innovation, telecommunication issues, computer security and privacy, risk analysis and communication, among others. Students from several CMU colleges enroll in these projects courses exposing EPP additional majors to working in truly interdisciplinary situations. Examples of past project course topics (<http://www.cmu.edu/epp/prospective/undergraduate/epp-project-courses/>) and final reports are available.

Additional Major in Engineering and Public Policy

The EPP department offers an additional major in Engineering and Public Policy (EPP) for students completing an undergraduate degree in engineering from any of the five traditional engineering departments in the engineering college. The engineering additional major leads to a fully accredited engineering degree that prepares students for traditional technical careers. EPP additional major engineers are not educated to be a different kind of engineer. Rather, their education is intended to enable them to be better, more socially responsible engineers in the traditional technical fields.

Additional Major in Science, Technology, and Public Policy

The EPP department offers an additional major in Science, Technology and Public Policy (STPP) for students completing an undergraduate B.S. degree outside of the engineering college. This includes students in the Mellon College of Science, the School of Computer Science, Tepper School of Business, and select majors in the Dietrich College and College of Fine Arts. Similar to the additional major in Engineering and Public Policy, the additional major in Science, Technology and Public Policy is meant

to broaden the perspectives on a student's primary major and provide additional skills for future careers.

Minor in Technology and Policy

The department also offers a minor in Technology and Policy. The Technology and Policy minor exposes students to issues at the interface of science, technology, and society, and how interdisciplinary approaches are needed to solve complex problems.

Minor in Information Security, Privacy and Policy

The department offers a minor in Information Security, Privacy and Policy for all majors in partnership with the School of Computer Science. The Information Security, Privacy and Policy minor offers students an understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics as they pertain to design, development and management of new information technologies.

Career Options with OUR Additional Majors

Students who select one of our additional majors graduate with an accredited engineering degree or complete science degree, and thus have all of the options for traditional technical careers as their single major classmates. A large portion of our additional major students pursue traditional technical careers after graduation in areas such as product development, consulting, project management, etc.

The advantage of the additional major is the added set of skills and perspectives, which allow a graduate of the program to improve the quality, sensitivity, and social responsiveness of their work, and the work of their colleagues. Employers recognize these skills and often view our graduates as more attractive for a traditional engineering or technical position. Firms contact the EPP department every year to recruit EPP graduates because of their satisfaction with the knowledge and skills acquired by EPP students. In addition, the additional major also opens up options for careers in policy analysis in federal, state, and local government or in public policy consulting firms. Alumni pursue careers in a range of companies to deal with issues like government regulation of technological systems, climate change impacts, product liability and safety, environmental control, telecommunications policy, energy systems, financial investment, and the social impact of large technological systems.

Students also choose to continue their formal education, doing graduate work in engineering, the social sciences, law, or interdisciplinary programs.

Faculty Advisors

Faculty in several departments serve as advisors and information resources to students selecting the EPP undergraduate programs. Given the interdisciplinary perspective of EPP, students may find that a faculty member outside their traditional major can provide support and guidance with EPP-related courses and career paths. The EPP Associate Department Head for Undergraduate Affairs is Deanna Matthews. Dr. Matthews can provide general academic advice and guidance for all EPP undergraduates. Other faculty affiliated with the undergraduate programs in EPP are:

- Civil Engineering: Peter Adams, Jared Cohon, Destenie Nock
- Chemical Engineering: Peter Adams, Neil Donahue
- Computer Science: Lorrie Cranor, Nicolas Christin
- Economics/Business: Nicholas Muller, Marvin Sirbu
- Electrical and Computer Engineering: Jon Peha, Ramteem Sioshansi, Marvin Sirbu
- Engineering and Public Policy: Erica Fuchs, Paulina Jaramillo, Valerie Karplus, Deanna Matthews, Granger Morgan
- Institute for Politics and Strategy: Baruch Fischhoff
- Mechanical Engineering: Jeremy Michalek, Kate Whitefoot
- Material Science and Engineering: Jay Whitacre
- Social and Decision Sciences: Paul Fischbeck

EPP Program Educational Objectives

The additional major in Engineering and Public Policy is accredited by the Engineering Accreditation Commission of ABET, <http://www.abet.org>.

Students who earn an additional major in Engineering and Public Policy at the undergraduate level do so in conjunction with a traditional engineering major. The elements of the EPP undergraduate program broaden the traditional scope of technical analysis to encompass an engineering solution's potential impact on society. Thus, our graduates have all of the skills as their peers in traditional engineering majors, but with a broader societal perspective and additional analysis skills. This enables our graduates:

- to understand the interface between technology and society and
- to help solve the complex, interdisciplinary systems problems facing our world in their careers.

Students will be able to work in a variety of career fields, including technical and non-technical, in industry, government or elsewhere where these broad skills are needed.

EPP Student Outcomes

By the end of the combined B.S. programs in a traditional engineering program and the EPP program, students should have attained the following:

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Course Requirements for the Additional Major in EPP

Minimum units for the additional major 106

Students pursuing an additional major in EPP must complete three sets of requirements: courses for the EPP additional major, courses for their traditional engineering major, and general education courses. The student should refer to the relevant sections of this catalog for the required courses in the traditional engineering major. The EPP additional major is designed to be completed with a traditional engineering major in the standard eight-semester time frame. However, additional units or course work may be required. Some courses for the EPP additional major may also satisfy requirements for traditional engineering courses or for general education courses.

Overview

| Course | Units |
|--|---------|
| 19-101 Introduction to Engineering and Public Policy | 12 |
| 19-201 Professional Issues in Engineering, Science, Technology and Public Policy | 1 |
| 73-102 Principles of Microeconomics | 9 |
| 36-220 Engineering Statistics and Quality Control (or other approved statistics course) | 9 |
| 19-301 Decision Making Methods for Engineers and Scientists or 19-469 Behavior, Decision and Policy or 84-369 Decision Science for International Relations or 88-223 Decision Analysis (or other approved decision science course) | 9 |
| 76-270 Writing for the Professions (or other approved writing course) | 9 |
| 19-351 Applied Methods for Technology-Policy Analysis | 9 |
| 19-451 EPP Projects I | 12 |
| 19-452 EPP Projects II | 12 |
| Three EPP Technology-Policy Electives | min. 24 |

Introductory Courses

| | | Units |
|--------|---|-------|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-201 | Professional Issues in Engineering, Science, Technology and Public Policy | 1 |

The two introductory courses prepare students for the additional major experience through discussion and assessment of technology-policy interactions. 19-101 Introduction to Engineering and Public Policy may be taken as the second introductory engineering course for engineering students. 19-201 Professional Issues in Engineering, Science, Technology and Public Policy is required in addition to any corresponding seminar course in a student's traditional degree program.

Core Area Courses

| | | |
|--|--|----|
| 73-102 | Principles of Microeconomics | 9 |
| EPP Statistics elective - one of the following, or other approved course: | | |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| EPP Decision Science elective - one of the following, or other approved course (9 units minimum): | | |
| 19-301 | Decision Making Methods for Engineers and Scientists | 9 |
| 19-469 | Behavior, Decision and Policy | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 88-223 | Decision Analysis | 12 |
| EPP Writing and Communications elective - one of the following, or other approved course | | |
| 76-270 | Writing for the Professions | 9 |

The four core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. 73-102 Principles of Microeconomics fulfills a CIT General Education course. Students who receive a pre-requisite waiver for 73-102 may take a higher-level economics course as a substitute with approval.

CivE, EnvE, MechE, and MSE students will complete the statistics elective as part of their traditional engineering majors. ChemE students will substitute the statistics elective for the Advanced Chemistry Elective. ECE students, who have a required course in probability for their traditional engineering major are encouraged to take 36-226 Introduction to Statistical Inference to fulfill the EPP statistics requirement. Students should complete the statistics requirement by the end of sophomore year. A statistics course is a prerequisite for the EPP Decision Science elective.

The EPP Decision Science elective fulfills either the CIT General Education Social Analysis and Decision Making requirement or a CIT General Education free elective. The EPP Writing and Communications course fulfills the CIT General Education Writing and Expressions requirement.

Technology-Policy Electives

- At least 3 courses of EPP Technology-Policy electives (24 units minimum)

EPP Technology-Policy Electives include courses that belong to three categories. First, EPP Technology-Policy Electives include courses that synthesize engineering analysis and social analysis perspectives and apply them to problems with substantial societal and technological components. Specific areas of interest for these courses are (1) energy, resources, and the environment, (2) risk assessment, (3) technology innovation, (4) urban engineering, (5) information and communication technology, and (6) product engineering and design, among others. Second, EPP Technology-Policy Electives include courses that teach methods or analysis skills necessary for solving complex problems. Examples include mathematical or statistical courses related to optimization or estimation, or economics courses related to economic analysis. Finally, EPP Technology-Policy Electives include courses that provide technical background for policy relevant issues. These courses are fundamental for understanding our current engineering systems and how proposed changes can be implemented. Examples include courses on electricity systems, engine design, or atmospheric systems. A sample of courses for EPP Technology-Policy Electives is below, a full list of approved courses is available from the department.

| | | |
|--------|--|------|
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 19-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |

| | | |
|--------|--|----|
| 19-429 | Climate Change Science and Solutions | 9 |
| 19-433 | Data Science for Technology, Innovation and Policy | 9 |
| 19-608 | Privacy Policy, Law, and Technology | 12 |
| 19-668 | Electric Vehicles: Technology, Economics, Environment and Policy | 12 |

The majority of 19-xxx EPP departmental courses are considered EPP Technology-Policy Electives. Exceptions will be identified when the courses are offered. Courses that are required or used for core area courses for the additional major can not be used as electives. Courses from other departments also are acceptable as electives with approval. Students should work with their advisors to define areas of concentration or a selection of breadth courses for the EPP Technology-Policy Electives.

Students are required to take at least three EPP Technology-Policy electives for a minimum of 24 units. Units may be added in any combination, but a maximum of one 3-unit course is permitted. Up to 9 units of 19-550 Undergraduate Research may be used with approval. Students may not use a required course from their traditional engineering major for these elective units. However, students may use an elective course from their traditional major requirements to meet the requirements of both their traditional engineering major and an EPP Technology-Policy elective, but the units for the course will not be double-counted toward units required for their degree. Some EPP Technology-Policy elective courses may fulfill requirements for CIT General Education categories (e.g., 19-411 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech is an I&I course), otherwise students use Free Elective units to complete this requirement.

Capstone Courses

| | | Units |
|--------|--|-------|
| 19-351 | Applied Methods for Technology-Policy Analysis | 9 |
| 19-451 | EPP Projects I | 12 |
| 19-452 | EPP Projects II | 12 |

The capstone courses synthesize the technical skills and knowledge from a student’s traditional major with the social science skills and broad perspective of the EPP major.

19-351 Applied Methods for Technology-Policy Analysis is a preparatory course for EPP Projects sequence. 19-351 may be completed as a co-requisite of 19-451 EPP Projects I. The course fulfills CIT General Education elective units.

19-451 EPP Projects I and 19-452 EPP Projects II are technology/policy projects which deal with research and development of recommendations for solving actual and critical problems currently affecting society. The students, faculty, and graduate student managers for the project are drawn from EPP, Social and Decision Sciences, and the Heinz College, and other CMU departments, and hence bring different areas of expertise to the structuring and solution of the problem. The topics for EPP Projects are drawn from diverse areas such as environmental systems and resources, public transportation, urban engineering problems, energy and fuel utilization, the interaction of law and technology, strategic materials and vulnerability of supply, technical issues in national security, and problems in automation, robotics, and communication technology. Students use Free Elective units to complete this requirement. 19-452 EPP Projects II serves as the capstone engineering design course experience for additional majors.

Notes on EPP additional major requirements

Students should follow the suggested curriculum timelines for completing the math, science, and engineering course requirements of the traditional major with the exception of the statistics elective which should be taken as early as possible and no later than the end of sophomore year.

Some courses as noted above may be used to fulfill requirements of general education courses. Acceptable courses for the CIT General Education requirements are maintained by the CIT Dean's Office. Students must submit a plan during their first-semester as an EPP student (usually Fall sophomore year) for these general education courses demonstrating their relevance to EPP.

Students must complete the minimum number of units as required by their traditional major for graduation. In some cases, students completing the EPP additional major may need to complete additional units to meet all requirements for the traditional major and EPP additional major.

In addition to any other graduation requirements (e.g., regarding course work, minimum QPA, pass/fail course work, etc.) of the student's traditional disciplinary major, students must earn a minimum QPA of 2.0 in all courses required for the EPP major.

Side-by-side curriculum charts (<http://www.cmu.edu/epp/prospective/undergraduate/epp-additional-major/curriculum-charts/>) of the curricula for the traditional engineering majors alone versus the traditional engineering

majors with the EPP additional major can assist students in determining the course requirements and scheduling needed to complete the degree requirements.

A proposed semester plan is below. Students work with their faculty advisors to determine the best sequence of courses given the varied requirements in the traditional engineering majors.

| Course | Semester |
|---|---------------------------|
| 19-101 Introduction to Engineering and Public Policy | First-year Spring |
| 73-102 Principles of Microeconomics | First-year Fall or Spring |
| 19-201 Professional Issues in Engineering, Science, Technology and Policy | Sophomore Fall |
| EPP Statistics Elective | Sophomore Fall or Spring |
| EPP Writing and Communications Elective | Sophomore Fall or Spring |
| EPP Decision Science Elective | Junior Fall |
| 19-351 Applied Methods for Technology-Policy Analysis | Junior Spring |
| 3 EPP Technology-Policy Electives | Junior and/or Senior year |
| 19-451 / 19-452 EPP Projects I and II | Senior Fall and Spring |

Course Requirements for the Additional Major in STPP

Minimum units required for additional major 106

Students pursuing an additional major in STPP must complete three sets of requirements: courses for the STPP additional major, courses for their traditional disciplinary major, and general education courses. The student should refer to the relevant sections of this catalog for the required courses in the traditional disciplinary major. The STPP additional major is designed to be completed with a traditional disciplinary major in the standard eight-semester time frame. However, additional units or course work may be required. Some courses for the STPP additional major may also satisfy requirements for traditional disciplinary majors or for general education courses.

Introductory Courses

| | | Units |
|--------|---|-------|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-201 | Professional Issues in Engineering, Science, Technology and Public Policy | 1 |

The two introductory courses prepare students for the additional major experience through discussion and assessment of technology-policy interactions. 19-101 Introduction to Engineering and Public Policy may qualify as a general education course in some majors. 19-201 Professional Issues in Engineering, Science, Technology and Public Policy is required in addition to any corresponding seminar course in a student’s traditional degree program.

Core Area Courses

| | | |
|--|--|----|
| 73-102 | Principles of Microeconomics | 9 |
| Statistics course — one of the following: | | |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| or other approved statistics course | | |
| STPP Decision Science course — one of the following: | | |
| 19-301 | Decision Making Methods for Engineers and Scientists | 9 |
| 19-469 | Behavior, Decision and Policy | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |
| or other approved decision science course | | |
| STPP Writing and Communications course — one of the following: | | |
| 76-270 | Writing for the Professions | 9 |

| | | |
|--------|--|---|
| 76-271 | Introduction to Professional and Technical Writing | 9 |
|--------|--|---|

or other approved writing and communications course

The four core area courses provide the foundational skills in the social sciences that are needed for robust analysis of policy problems. For students in SCS and MCS, the economics, decision science, and writing course selections may qualify as general education courses, and the statistics elective may qualify for a math/science requirement. For students in DC and CFA, some core area requirements may be fulfilled by traditional program requirements or general education courses. Students should consult with their advisors in both programs to assure that courses are meeting requirements and providing appropriate depth of content. Students who receive a pre-requisite waiver for 73-102 may complete a higher-level economics course as a substitute with approval.

Technology-Policy Electives

3 courses **24 minimum units**

STPP Technology-Policy Electives include courses that belong to three categories. First, STPP Technology-Policy Electives include courses that synthesize technical analysis and social analysis perspectives and apply them to problems with substantial societal and technological components. Specific areas of interest for these courses are (1) energy, resources, and the environment, (2) risk assessment, (3) technology innovation, (4) urban engineering, (5) information and communication technology, and (6) product development and design, among others. Second, STPP Technology-Policy Electives include courses that teach methods or analysis skills necessary for solving complex problems. Examples include mathematical or statistical courses related to optimization or estimation, or economics courses related to economic analysis. Finally, STPP Technology-Policy Electives include courses that provide technical background for policy relevant issues. These courses are fundamental for understanding our current technical systems and how proposed changes can be implemented. Examples include courses on electricity systems, telecommunication systems, engine design, or atmospheric systems. A sample of courses for STPP Technology-Policy Electives is below, a full list of approved courses is available from the department.

| | | |
|--------|--|------|
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 19-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-421 | Emerging Energy Policies | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 19-429 | Climate Change Science and Solutions | 9 |
| 19-433 | Data Science for Technology, Innovation and Policy | 9 |
| 19-608 | Privacy Policy, Law, and Technology | 12 |
| 19-668 | Electric Vehicles: Technology, Economics, Environment and Policy | 12 |

The majority of 19-xxx EPP departmental courses are considered STPP Technology-Policy Electives. Exceptions will be identified when the courses are offered. Courses that are required or used for core area courses for the additional major can not be used as electives. Courses from other departments also are acceptable as electives with approval. Students should work with their advisors to define areas of concentration or a selection of breadth courses for the STPP Technology-Policy Electives.

Students are required to take at least three STPP Technology-Policy electives for a minimum of 24 units. Units may be added in any combination, but a maximum of one 3-unit course is permitted. Up to 9 units of 19-550 Undergraduate Research may be used with approval. Students may not use a required course from their traditional disciplinary major for these elective units. However, students may use an elective course from their traditional major requirements to meet the requirements of both their traditional engineering major and an STPP Technology-Policy elective, but the units for the course will not be double-counted toward units required for their degree. Some STPP Technology-Policy elective courses may fulfill general education requirements for traditional major programs.

Capstone Courses

| | | |
|--------|--|----|
| 19-351 | Applied Methods for Technology-Policy Analysis | 9 |
| 19-451 | EPP Projects I | 12 |
| 19-452 | EPP Projects II | 12 |

The capstone courses synthesize the technical skills and knowledge from a student's traditional major with the social science skills and broad perspective of the STPP additional major.

19-351 Applied Methods for Technology-Policy Analysis is a preparatory course for the EPP Projects sequence. 19-351 may be completed as a co-requisite of 19-451 EPP Projects I.

19-451 EPP Projects I and 19-452 EPP Projects II are technology/policy projects which deal with research and development of recommendations for solving actual and critical problems currently affecting society. The students, faculty, and graduate student managers for the project are drawn from the EPP and STPP programs, Social and Decision Sciences, and the Heinz College, and other CMU departments, and hence bring different areas of expertise to the structuring and solution of the problem. The topics for EPP Projects are drawn from diverse areas such as environmental systems and resources, public transportation, urban engineering problems, energy and fuel utilization, the interaction of law and technology, strategic materials and vulnerability of supply, technical issues in national security, and problems in automation, robotics, and communication technology. These capstone courses may qualify as capstone experience courses or general education courses in some major programs.

Notes on STPP additional major requirements

Students should follow the suggested curriculum timelines for completing the course requirements of their primary major program where necessary and will work with both their primary program advisor and the STPP advisor to assure that requirements for both degrees are met.

Students must complete the minimum number of units as required by their primary major for graduation. In some cases, students completing the STPP additional major may need to complete additional units to meet all requirements for the primary major and STPP additional major.

In addition to any other graduation requirements (e.g., regarding course work, minimum QPA, pass/fail course work, etc.) of the student's primary major, students must earn a minimum QPA of 2.0 in all courses required for the STPP additional major.

Integrated B.S./M.S. Programs

B.S. integrated with M.S. in Engineering and Public Policy

CMU undergraduate students, regardless of whether they complete an undergraduate additional major in EPP or STPP or not, may plan a course of study that leads to completing both their undergraduate B.S. degree and an MS in Engineering and Public Policy. This course of study will ordinarily require two additional semesters of study beyond that required for an undergraduate degree, although advanced placement or other study may reduce this time. Some coursework towards the MS may be completed during the student's senior year, however no courses taken may count for both a BS program and the MS in EPP. Students interested in the program should contact their advisor for details on the application process and course requirements. See the EPP website for more information about the MS in EPP program requirements (<https://www.cmu.edu/epp/prospective/ms-in-epp/>) including curriculum.

B.S. integrated with M.S. in Public Policy and Management

Students may also combine their undergraduate degree program and EPP or STPP additional major program with a master's degree in the H. John Heinz College of Public Policy and Management in a five-year course of study. During the third year of study, the student applies to the Heinz College for admission to the master's program; an academic record of B average or better is normally a prerequisite for admittance. For general information on Heinz 3-1-1 programs please contact the Heinz College or refer to their website.

Minors in Engineering and Public Policy

MINOR IN TECHNOLOGY AND POLICY

The department offers a minor in Technology and Policy. This minor allows students to sample the EPP requirements and develop exposure and awareness to issues at the interface of science, technology, and society.

Pre-requisites: Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or higher level economics course) and statistics (36-202 Methods for Statistics & Data Science or higher level statistics course) in order to pursue the Technology and Policy Minor.

| Course Requirements | Units |
|--|-------|
| 19-101 Introduction to Engineering and Public Policy | 12 |

| | | |
|-----------|---|----|
| 19-301 | Decision Making Methods for Engineers and Scientists (or other approved Decision Science course) | 9 |
| or 19-351 | Applied Methods for Technology-Policy Analysis | |
| 19-451 | EPP Projects I | 12 |
| xx-xxx | Two EPP Technology-Policy Electives | 18 |

EPP Technical Electives include courses that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is available from the EPP Department. Example Technology-Policy electives include:

| | | |
|--------|--|------|
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 19-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 19-429 | Climate Change Science and Solutions | 9 |
| 19-433 | Data Science for Technology, Innovation and Policy | 9 |
| 19-534 | Usable Privacy and Security | 9 |

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student's primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student's primary major or courses fulfilling general education requirements may be counted, however.

Details of this program are provided in the discussion of CIT minors; see Technology and Policy Minor Description (p. 174).

MINOR IN INFORMATION SECURITY, PRIVACY AND POLICY

Lujo Bauer, Director

Interdisciplinary minor offered by both CIT and SCS

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, they are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

| | | |
|--------|---|----|
| 17-331 | Information Security, Privacy, and Policy | 12 |
|--------|---|----|

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

| | | |
|--------|-------------------------------------|---|
| 17-333 | Privacy Policy, Law, and Technology | 9 |
|--------|-------------------------------------|---|

Students may substitute 12-unit version of this course: 19-608, 17-733, or 95-818.

PRIVACY ELECTIVES

| | | |
|--------------------------------|-----------------------------------|-------|
| Complete a minimum of 9 units: | | Units |
| 19-534/17-334/05-416 | Usable Privacy and Security | 9 |
| 19-602/17-702 | Current Topics In Privacy Seminar | 3 |
| 17-731 | Foundations of Privacy | 12 |

TECHNOLOGY AND POLICY ELECTIVES

| | | |
|--------------------------------|---|-------|
| Complete a minimum of 9 units: | | Units |
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 17-562 | Law of Computer Technology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-639 | Policies of the Internet | 12 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

| | | |
|---------------|--|------|
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-356 | Introduction to Cryptography | 12 |
| 19/17-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 19-534/17-334 | Usable Privacy and Security | 9 |
| 18-334 | Network Security | 12 |
| 18-335 | Secure Software Systems | 12 |
| 18-435 | Foundations of Blockchains | 12 |

*Course 18-733 Applied Cryptography is also an approved security elective.

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department. In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Notes on EPP Undergraduate/ Graduate Level Courses

Many courses taught by the department (19-XXX courses) are offered to undergraduate and graduate students. These “dual level” courses are offered in two formats:

- Some courses are taught under both an undergraduate and graduate number. An example is 19-403 Policies of Wireless Systems, also offered as 19-713. In these types of courses, students who sign up under the 700-level (graduate) course number may be expected to perform the same coursework at a higher level, and/or complete additional coursework, compared to 400-level students. Undergraduates who choose to take the course under the graduate number will be also be expected to work at the higher expectation/coursework level.
- Other courses are taught under a 600 level number. An example is 19-668 Electric Vehicles: Technology, Economics, Environment and Policy. These courses may be taken by undergraduates as a senior level course, or by graduate students as a graduate level course. As with dual number courses, graduate level students or undergraduates taking the course for graduate credit may be required to perform coursework at a higher level and/or complete additional coursework. Undergraduates who are taking a 600 level course for graduate credit should identify this fact to both the course instructor and to their EPP department advisor.

Students who have questions about the requirements of a specific EPP 400/700, or 600 level course, should contact the course instructor. Some courses have pre-requisites which may be waived for students given prior background.

Faculty

PETER ADAMS, Thomas Lord Professor of Civil and Environmental Engineering and Engineering and Public Policy / Department Head, Engineering and Public Policy; Professor of Civil and Environmental Engineering / Engineering and Public Policy – Ph.D., Caltech; Carnegie Mellon, 2001–

TIMOTHY BROWN, Professor of Engineering and Public Policy; Director of Academics, Carnegie Mellon University Africa – Ph.D., California Institute of Technology; Carnegie Mellon, 2013–

KATHLEEN M. CARLEY, Professor, Computer Science/ Tepper School of Business/ Social and Decision Sciences/ H. John Heinz III College / Engineering and Public Policy – Ph.D., Harvard University; Carnegie Mellon, 1984–

NICOLAS CHRISTIN, Professor, Computer Science/ Engineering and Public Policy/ Cylab – Ph.D., University of Virginia; Carnegie Mellon, 2005–

JARED L. COHON, University Professor, Civil and Environmental Engineering / Engineering and Public Policy; President Emeritus – Ph.D., MIT; Carnegie Mellon, 1997–

CHRISTOPHE COMBEMALE, Assistant Research Professor, Engineering and Public Policy – PhD, Carnegie Mellon University; Carnegie Mellon, 2023–

LORRIE FAITH CRANOR, Director and Bosch Distinguished Professor in Security and Privacy Technologies, CyLab; FORE Systems Professor, Computer Science / Engineering and Public Policy – D.Sc., Washington University, St. Louis; Carnegie Mellon, 2003–

NEIL M. DONAHUE, Thomas Lord Professorship in Chemistry; University Professor of Chemical Engineering / Chemistry / Engineering and Public Policy – Ph.D., MIT; Carnegie Mellon, 2000–

PEDRO FERREIRA, Professor of The H. John Heinz III College / Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010–

PAUL S. FISCHBECK, Professor of Social and Decision Sciences / Engineering and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1990–

BARUCH FISCHHOFF, Howard Heinz University Professor, Professor of Engineering and Public Policy / Institute for Politics and Strategy – Ph.D., Hebrew University; Carnegie Mellon, 1987–

ERICA R. H. FUCHS, Professor of Engineering and Public Policy – Ph.D., MIT; Carnegie Mellon, 2007–

PAULINA JARAMILLO, Professor of Engineering and Public Policy and CMU Africa – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007–

VALERIE KARPLUS, Professor of Engineering and Public Policy – PhD, MIT; Carnegie Mellon, 2020–

RAMAYYA KRISHNAN, Dean of The H. John Heinz III College; William W. and Ruth F. Cooper Professor of Management Science and Information Systems; Professor of Engineering and Public Policy – Ph.D., University of Texas at Austin; Carnegie Mellon, 1987–

DEANNA MATTHEWS, Teaching Professor and Associate Department Head for Undergraduate Affairs, Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001–

JEREMY J. MICHALEK, Professor of Mechanical Engineering / Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 2005–

M. GRANGER MORGAN, Hammerschlag University Professor of Engineering; Professor of Engineering and Public Policy / Electrical and Computer Engineering / The H. John Heinz III College – Ph.D., University of California, San Diego; Carnegie Mellon, 1974–

NICHOLAS MULLER, Lester and Judith Lave Professor of Economics, Engineering, and Public Policy, Tepper School of Business / Engineering and Public Policy; Associate Department Head for Graduate Affairs, Engineering and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017–

DESTENIE NOCK, Assistant Professor, Civil and Environmental Engineering/ Engineering and Public Policy – PhD, University of Massachusetts, Amherst; Carnegie Mellon, 2019–

JON M. PEHA, Professor of Engineering and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1991–

ALLEN ROBINSON, Director, CMU-Africa; Raymond J. Lane Distinguished University Professor, Mechanical Engineering/Engineering and Public Policy; Associate Dean for International Programs in Africa, College of Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1998–

RAMTEEN SIOSHANSI, Professor, Engineering and Public Policy – Ph.D., University of California, Berkeley; Carnegie Mellon, 2023–

MARVIN A. SIRBU, Professor of Engineering and Public Policy / Industrial Administration / Electrical and Computer Engineering – Sc.D., MIT; Carnegie Mellon, 1985–

ESWARAN SUBRAHMANYAN, Research Professor, Engineering Research Accelerator/ Engineering and Public Policy – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1984–

JEANNE VANBRIESEN, Duquesne Light Company Professor, Professor of Civil and Environmental Engineering / Engineering and Public Policy – Ph.D., Northwestern University; Carnegie Mellon, 1999–

JAY WHITACRE, Trustee Professor in Energy, Materials Science and Engineering / Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 2007–

KATE WHITEFOOT, Associate Professor of Mechanical Engineering / Engineering and Public Policy – Ph.D., University of Michigan; Carnegie Mellon, 2016–

PHILLIP YU, Associate Teaching Professor and Executive Director of Master's Programs, Engineering and Public Policy – PhD, Tufts University; Carnegie Mellon, 2023–

Emeriti Faculty

JAY APT, Professor, The Tepper School of Business/Engineering and Public Policy, Emeritus – Ph.D, Massachusetts Institute of Technology; Carnegie Mellon, 2000–

ALFRED BLUMSTEIN, J. Erik Jonsson University Professor of Urban Systems and Operations Research; Professor of The H. John Heinz III College / Engineering and Public Policy, Emeritus – Ph.D., Cornell University; Carnegie Mellon, 1969–

ELIZABETH CASMAN, Associate Research Professor of Engineering and Public Policy, Emeritus – PhD, The Johns Hopkins University; Carnegie Mellon, 1997–

JAMES GOODBY, Distinguished Service Professor, Emeritus – A.B., Harvard ; Carnegie Mellon, 1989–

MICHAEL GRIFFIN, Research Professor of Engineering and Public Policy, Emeritus – PhD, University of Rhode Island; Carnegie Mellon, 2000–

CHRISTOPHER T. HENDRICKSON, Hammerschlag University Professor of Civil and Environmental Engineering / Engineering and Public Policy / Heinz College of Information Systems and Public Policy, Emeritus – PhD, MIT; Carnegie Mellon, 1978–

DAVID A. HOUNSHELL, David M Roderick Professor of Technology and Social Change; Professor of Social and Decision Sciences / Engineering and Public Policy, Emeritus - Ph.D., University of Delaware; Carnegie Mellon, 1991-

MARIJA ILIC, Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus - D.Sc., University of Washington, St. Louis; Carnegie Mellon, 2002-

INDIRA NAIR, Vice Provost for Education, Carnegie Mellon University; Professor of Engineering and Public Policy, Emeritus - PhD, Northwestern University; Carnegie Mellon, 1978-

EDWARD S. RUBIN, The Alumni Chair Professor of Environmental Engineering and Science; Engineering and Public Policy/Mechanical Engineering, Emeritus - Ph.D, Stanford University; Carnegie Mellon, 1969-

MITCHELL J. SMALL, The H. John Heinz III Professor of Environmental Engineering, Civil and Environmental Engineering/ Engineering and Public Policy, Emeritus - Ph.D, University of Michigan; Carnegie Mellon, 1982-

SAROSH TALUKDAR, Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus - Ph.D., Purdue University; Carnegie Mellon, 1974-

JOEL A. TARR, Richard S. Caliguiri University Professor of Urban and Environmental History and Policy, History/Engineering and Public Policy/ Heinz College of Information Systems and Public Policy, Emeritus - Ph.D, Northwestern University; Carnegie Mellon, 1967-

ROBERT M. WHITE, University Professor of Electrical and Computer Engineering / Engineering and Public Policy, Emeritus - Ph.D., Stanford University; Carnegie Mellon, 1993-

Department of Engineering and Public Policy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

19-101 Introduction to Engineering and Public Policy

Fall and Spring: 12 units

This course examines interactions between technology and society, and the related processes of public and private decision-making. Classes involve a mix of lecture, discussion, and hands-on activities where students tackle interdisciplinary issues with both quantitative and qualitative methods. Students complete individual and group assignments that build skills in analysis and communication relevant for future careers. Past project topics include: using drone imaging to assess algal blooms in Lake Erie, incorporating renewable electricity generation on campus, reducing credit card fraud through data analytics, and creating standards for additive manufacturing of critical airplane parts.

19-201 Professional Issues in Engineering, Science, Technology and Public Policy

Fall: 1 unit

The course provides an overview of the academic and professional domain of technology-centered policy. Content includes career exploration, networking practice, ethics and professional responsibilities, academic advising, alumni speakers, and other topics as relevant. Intended for sophomores enrolling in the Engineering and Public Policy (EPP) Additional Major and the Science, Technology and Public Policy (STPP) Additional Major.

19-211 Ethics and Policy Issues in Computing

Spring: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

19-213 The American Railroad: Decline and Renaissance in the Age of Deregulation

Intermittent: 6 units

Railroads in the USA are often considered as a subject for nostalgia or public sector failure, an image largely based on passenger service. However, the USA's private sector freight rail industry is considered a model for the world as the result of its renaissance following deregulation in 1980. This is a "stealth" industry whose history and economics are both intertwined and complex. Students will gain a basic understanding of the industry's history and economics and its role in the national transportation network, with special attention to the past half-century. In addition, students will participate in small group research projects in particular areas of special interest - for example, economic history, industry and safety culture, network economics, utility regulation or transportation policy.

19-301 Decision Making Methods for Engineers and Scientists

Fall: 9 units

This course covers various economic, statistical, and decision analysis techniques used for examining complex decisions where technology, society, and policy interconnect. Topics covered include: estimation techniques, benefit-cost analysis, decision trees, dealing with uncertainty, risk perception and analysis, survey design and implementation, utility theory, heuristics and biases in inference and prediction, methods for combining information from different sources and dealing with conflicting objectives.

Prerequisites: 36-217 Min. grade C or 36-219 Min. grade C or 19-250 Min. grade C or 36-220 Min. grade C

19-303 Cryptocurrencies, Blockchains and Applications

Spring: 9 units

Note: Previously offered as 19-355. Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies. Prerequisites: Introduction to Computer Systems or equivalent strongly recommended

19-351 Applied Methods for Technology-Policy Analysis

Spring: 9 units

This course synthesizes concepts from economics, statistics, decision analysis, and other humanities and social science areas as they relate to analysis of technology and public policy issues. Students will focus on applying skills, tools, and techniques of social science to critically examine issues of current importance to society that have engineering systems at the core, and how public policy can be informed by the results of these analyses. Students will discover the relationship between formulating research questions considering a wide range of perspectives (e.g., political, ethical, social, economic, and legal aspects) and implementing the appropriate research methods for answering them. The course will emphasize interpretation and communication of analysis results in written and oral presentation, especially to non-technical audiences. As a precursor to the EPP Project courses, the course also prepares EPP juniors for structuring real-world problems into a feasible work plan, and to deal with revising work plans as work proceeds.

19-402 Telecommunications Technology and Policy for the Internet Age

Intermittent: 12 units

Modern telecommunications is the nervous system of society. The Internet and wireless communications have transformed every aspect of our modern life. This course provides a comprehensive introduction to basic principles of telecommunications technology and the legal, economic, and regulatory environment of today's networks. Topics covered include the fundamentals of communication network technologies, including video, voice, and data networks; the rising dominance of wireless networks; principles behind telecommunications regulation from common carrier law and natural monopoly to information diversity, privacy and national security; traffic differentiation on the Internet and the debate over network neutrality; universal service and the digital divide; mergers, antitrust, and the changing industrial structure of the communications sector. We will explore current topical questions such as the future of competition; the shift of entertainment video from cable and satellite to Internet delivery; how cloud computing concepts are transforming networks; and communications support for the Internet of Things. Comparison with European approaches to communications regulation. Special emphasis on how new technologies have altered, and are altered by, regulation. Junior, Senior or graduate standing required.

Prerequisites: 73-100 and 73-102

19-403 Policies of Wireless Systems

Intermittent: 12 units

This course will address public policy issues related to wireless systems. It investigates policies related to a wide variety of emerging wireless systems and technologies, including current and next-generation cellular systems, wifi and white space devices, emerging methods of accessing spectrum, communications systems for emergency responders (firefighters, police, emergency medical services), current and next-generation television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in using scarce spectrum efficiently, in promoting public safety and homeland security, and in protecting privacy and security. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Senior or graduate standing required.

19-411 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech

Fall: 9 units

Science and Innovation Leadership for the 21st Century introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors, seniors and amp; graduate students.

19-421 Emerging Energy Policies

Intermittent: 9 units

Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, prince analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

19-425 Sustainable Energy for the Developing World

Fall and Spring: 9 units

This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/>)

19-427 Special Topics: Energy Innovation and Entrepreneurship

Fall: 9 units

Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/>)

19-429 Climate Change Science and Solutions

Fall and Spring: 9 units

This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no knowledge of meteorology or atmospheric science is needed. College-level physics, as well as basic calculus and basic chemistry, is, however, needed. The second part will describe the projected consequences of climate change, as well as those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be used to prevent dangerous climate change.

19-433 Data Science for Technology, Innovation and Policy

Intermittent: 9 units

Students will learn how to use R to collect, organize, and analyze data in technology, innovation, and policy-related domains. The focus will be on the practical issues faced when conducting data analyses, correctly implementing and interpreting statistical models, and summarizing results for clients and research purposes.

19-440 Combustion and Air Pollution Control

Intermittent: 9 units

Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and postcombustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples.

19-451 EPP Projects I

Fall and Spring: 12 units

Students work in multidisciplinary teams (engineers and scientists, humanities and social scientists, public policy and management graduates) on a cutting edge project topic with very little in the way of pre-digested analysis or solutions. Topics include both technical and social dimensions, multiple constraints on the solutions, and require multi-dimensional analyses. Students are given a general goal, and are expected to discover existing knowledge on the topic, and to research existing technologies and relevant policies. Using this background and their technical and social analysis education as appropriate, students then create new knowledge on the subject and analyzing technology impacts, policy alternatives, or other relevant options as topics necessitate. This knowledge is communicated to an external advisory panel, selected from experts and constituencies of importance to the issue through formal presentations and a written report. #19451 is the first of two EPP Projects course experiences for EPP additional majors, students taking EPP Projects I are learning how to use their skills from prior EPP courses in solving complex, unstructured problems and developing skills for effective project completion.

19-452 EPP Projects II

Fall: 12 units

Students work in multidisciplinary teams (engineers and scientists, humanities and social scientists, public policy and management graduates) on a cutting edge project topic with very little in the way of pre-digested analysis or solutions. Topics include both technical and social dimensions, multiple constraints on the solutions, and require multi-dimensional analyses. Students are given a general goal, and are expected to discover existing knowledge on the topic, and to research existing technologies and relevant policies. Using this background and their technical and social analysis education as appropriate, students then create new knowledge on the subject and analyzing technology impacts, policy alternatives, or other relevant options as topics necessitate. This knowledge is communicated to an external advisory panel, selected from experts and constituencies of importance to the issue through formal presentations and a written report. The second of two EPP Projects course experiences for EPP additional majors, EPP Projects II is the capstone course. Students apply their skills and knowledge from EPP Projects I, demonstrating project framing, decomposition, and developing analyses. Students in this second course are expected to be course leaders, assisting students taking the course for the first time in navigating project communications and tasks.

19-469 Behavior, Decision and Policy

Intermittent: 9 units

Behavioral science can inform policy making in three ways: (a) improving two-way communication between the public and policy makers; (b) creating policies that make realistic assumptions about human behavior; (c) disciplining the expert judgment needed to analyze risks. The course will introduce and discuss the technical and ethical foundations of behavioral research and risk analysis, setting them in their historical, social, and political context. It will apply them to a wide variety of technology-related policies, including energy (e.g., conservation, nuclear power), environment (e.g., climate, pollution), health (e.g., vaccines, COVID-19), national security (e.g., terrorism, intelligence analysis), and others, including ones proposed by students. Students will acquire a critical perspective on policies in their lives, society, and profession. The course is open to juniors, seniors, and graduate students, who have not taken 84369/84669.

19-500 Directed Study in EPP: Undergraduate

All Semesters

Students may do undergraduate research as one course for EPP technical elective credit, with an EPP faculty member, or on an approved project with a faculty member from another department. The research credits must be pre-approved by your advisor, and should result in a written product, one copy of which should be sent to EPP.

19-534 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an essential role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user-interface problems related to privacy and security and to give them experience in understanding and designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Students will also work on a group project throughout the semester. The course is open to all students who have technical backgrounds. The 12-unit course numbers (17-734, 5-836, 19-734) are for PhD students and masters students. Students enrolled in these course numbers will have extended homework assignments and will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit course numbers (17-334, 5-436, 19-534) are for undergraduates and masters students (if permitted by their program).

19-550 Undergraduate Research

Intermittent

Students may do undergraduate research as one course for EPP technical elective credit, with an EPP faculty member, or on an approved project with a faculty member from another department. The research credits must be pre-approved by your advisor, and should result in a written product, one copy of which should be sent to EPP.

19-602 Current Topics In Privacy Seminar

Fall and Spring: 3 units

In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

19-603 Data Science for Technology, Innovation and Policy

Intermittent: 12 units

Students will learn how to use R to collect, organize, and analyze data in technology, innovation, and policy-related domains. The focus will be on the practical issues faced when conducting data analyses, correctly implementing and interpreting statistical models, and summarizing results for clients and research purposes.

19-605 Engineering Privacy in Software

Spring: 12 units

Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/>)

19-608 Privacy Policy, Law, and Technology

Fall: 12 units

This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

19-617 Infrastructure Management

Intermittent: 12 units

This course takes a broad view of infrastructure systems to include physical infrastructure and information networks. The course will consider the need to protect these critical infrastructures from both degradation as well as malicious attacks. Infrastructure management generally depends on public-private partnerships to ensure long-term viability. We will look at relevant academic literature on the topics of infrastructure needs and requirements. We will explore the use of automated sensing and computer network systems to facilitate management.

19-624 Emerging Energy Policies

Intermittent: 12 units

Interested in what's happening in energy policy and how to analyze potential policy options in response? Focusing on current hot topics in energy policy, students will learn the basic principles of public policy analysis and underlying techniques such as program evaluation, cost benefit analysis, life cycle analysis, price analysis, and risk analysis as well as the variety of policy mechanisms available. Class time will include a combination of faculty and guest speaker lectures, discussion of issues, videos, and problem solving. Students will review and edit Wikipedia entries on an energy policy topic of their choice, and then analyze policy options resulting in an executive summary or paper on that topic. While the course has no prerequisites, students should feel comfortable with scientific and technical topics. Upon completion of this course, students should have a deeper and more strategic understanding of the opportunities and challenges associated with emerging energy policies. Open to seniors. Open to juniors with permission only.

19-625 Sustainable Energy for the Developing World

Fall and Summer: 12 units

This course examines the current state of the energy system in developing countries and the challenges these countries will face in sustainably meeting their energy needs in the 21st century. The following are examples of questions and issues we will cover throughout the semester. What is the current status of the energy system in the developing world? What is the role of energy in supporting economic growth and alleviating poverty? What are the future energy needs of developing countries? What are the challenges developing countries will face as they build/improve their energy systems? What technologies are available to meet the energy challenges in the developing world?

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/>)

19-627 Special Topics: Energy Innovation and Entrepreneurship

Fall: 12 units

Want to be an energy innovator, business entrepreneur, social entrepreneur, or intrapreneur? Students in this class will learn the fundamentals of energy innovation and entrepreneurship, and how innovation and entrepreneurship in energy differs from that in other fields. Students will then develop a business and non-market strategy for an idea of their own, or in response to a real-world challenge proposed by a business, industry, or a non-governmental organization. The resulting strategy can, if students wish, be submitted for student competitions that typically take place each spring throughout the United States.

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5/>)

19-629 Climate Change Science and Solutions

Fall and Spring: 12 units

This course consists of four parts. The first part will provide a primer for those who are curious about the physical mechanisms by which climate is determined, and by which climate change occurs. The treatment of these mechanisms will not be overly quantitative, and no knowledge of meteorology or atmospheric science is needed. College-level physics, as well as basic calculus and basic chemistry, is, however, needed. The second part will describe the projected consequences of climate change, as well as those that are already occurring. This part will also familiarize students with how societies might adapt to these changes. The third part will explore (and critique) some of the tools that decision-makers use to quantify and compare the damages caused by these consequences. The final part of the course will discuss some of the technologies that could be used to prevent dangerous climate change.

19-639 Policies of the Internet

Fall: 12 units

This course will address public policy issues related to the Internet. This may include policy issues such as network neutrality and the open Internet, Internet governance and the domain name system (and the role of the United Nations), copyright protection of online content, regulation of indecency and pornography, universal access to Internet and Internet as a "human right", government surveillance of the Internet, Internet privacy and security, and taxation of electronic commerce. It will also teach some fundamentals of Internet technology. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Senior or graduate standing required.

19-640 Dynamic Network Analysis

Spring: 12 units

Who knows who? Who knows what? Who communicates with whom? Who is influential? How do ideas, diseases, and technologies propagate through groups? How do social media, social, knowledge, and technology networks differ? How do these networks evolve? How do network constrain and enable behavior? How can a network be compromised or made resilient? Such questions can be addressed using Network Science. Network Science, a.k.a. social network analysis and link analysis, is a fast-growing interdisciplinary field aimed at understanding simple and high dimensional networks, from both a static and a dynamic perspective. Across an unlimited application space, graph theoretic, statistical, and simulation methodologies are used. An interdisciplinary perspective on network science is provided, with an emphasis on high-dimensional dynamic data. The fundamentals of network science, methods, theories, metrics and confidence estimation, constraints on data collection and bias, and key research findings and challenges are examined. Illustrative networks discussed include social media based (e.g., twitter), disaster response, organizational, semantic, political elite, crises, terror, and P2P networks. Critical procedures covered include: basic centralities and metrics, group and community detection, link inference, network change detection, comparative analytics, and big data techniques. Applications from business, science, art, medicine, forensics, social media and numerous other areas are explored. Key issues addressed: Conceptualization, measurement, comparison and evaluation of networks. Identification of influential nodes and hidden groups. Network emergence, evolution, change and destabilization. Graduate course taught every other year. Prerequisite: Undergraduate-level statistics course or instructor permission. Linear algebra is recommended. Students are encouraged to bring and use their own data, or to use provided data.

19-654 Regulation of Internet Edge Platforms

Fall: 6 units

Social media, search and e-commerce platforms are under attack all over the world: antitrust lawsuits, complaints about "fake news," partisan bias, and disinformation on social media, calls to remove liability protections for platforms that post user-provided content, to regulate content and online marketplaces. In this course we will examine competing economic and policy approaches to the treatment of these platforms. We will examine where these companies fit in the Internet ecosystem; how these firms make money (e.g. targeted advertising); traditional principles of antitrust and their application to multi-sided platforms; issues of Free Speech versus Disinformation on social networks, and how these firms differ from traditional media; and a comparison of proposals for structural versus behavioral regulation. Readings will be drawn from technical, economic, legal and policy sources. Students will be encouraged to contrast competing approaches to these issues via in-class debates and written assignments.

19-658 Special Topics: Corporate Venturing & Innovation

Intermittent: 6 units

: Startups aren't the only career destination for aspiring and experienced entrepreneurs - large, established companies need entrepreneurs more than ever to help them avoid the risk of being disrupted. The future survival of many large companies is in the hands of entrepreneurs who understand both technology and business - learn the skills you will need to engage corporate executives on the topic of corporate venturing. This course is created to help entrepreneurs design corporate venturing programs for large companies who want to avoid being disrupted by innovative and more nimble startups *How can you convince corporate executives to invest in corporate venturing capabilities? *How can you be successful as an entrepreneur inside a large company that is set on its ways? *How can a large company compete with faster and more nimble startups by building their own?

19-659 Economic Regulation of Networked Industries

Fall: 6 units

Economic Regulation of Networked Industries; This course will examine principles of economic regulation of networked industries such as gas, electricity, water and telecommunications, including economic justifications for price regulation (e.g. natural monopoly); alternative approaches to price regulation (Rate of Return, Price Caps), cost allocation and pricing in multiproduct industries (e.g. Ramsey prices); tariff design (single and multipart tariffs, capacity charges, peak load pricing); regulation in the presence of competition (cross subsidy and predatory pricing; access pricing); and institutional issues in regulatory agencies (design of independent regulatory agencies, incorporation of public input, public choice theory, regulatory capture).

Prerequisite: 73-102

19-664 Special Topics: Advancing Low Carbon Transition in Industry

Intermittent: 12 units

As a widely used and globally traded product, steel is essential to modern life, but its production is highly energy intensive and accounts for roughly 8% of global greenhouse gas emissions. This project course will work with a major U.S. and Pittsburgh-based steel producer to assess technology pathways for the decarbonization of their organization. Students will learn and apply engineering economic approaches as well as perspectives from organizational processes and business strategy to analyze and compare decision alternatives. Skills to be acquired include deep understanding of industrial processes and decarbonization technologies, engineering cost and real options analysis, business strategy and organization, the role of public policy, and project workflow management and presentation skills. The course will involve regular interaction with the executive sponsor and technical lead, as well as experts on steelmaking technology and climate policy, with high potential for impact.

19-666 Energy Policy and Economics

Intermittent: 6 units

This course will begin with a review of microeconomic concepts and tools necessary for analysis of the topics covered in the class. The course will explore how past energy technology policies and choices are intertwined with pathways of economic development, social impacts, macroeconomic measurement and performance. This course will explore how a wide variety of policy mechanisms- technology policy, utility regulation and restructuring, emissions policies, multilateral interventions and agreements, and corporate strategies-can shape energy use and the environmental impacts of energy systems. Study examples will draw from both developed and developing countries.

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5>)

19-668 Electric Vehicles: Technology, Economics, Environment and Policy

Intermittent: 12 units

In this course, students will read academic literature, government documents, and popular press to develop a broad understanding of the technology, economic, environmental and policy dimensions of electric vehicles. Topics may include (1) TECHNOLOGY: Battery technology, design, application, degradation and innovation; electric vehicle technologies and designs; the electric power grid; (2) ECONOMICS: cost; consumer behavior; infrastructure; electricity dispatch; automotive externalities; the Gruenspecht effect; (3) ENVIRONMENT: life cycle assessment; air pollution; greenhouse gas emissions; marginal grid emission factors; renewables; vehicle to grid; hydrogen; (4) POLICY: effectiveness, efficiency, uncertainty and equity; short-run versus long-run effects; fleet standards; incentives; mandates; policy interactions; intellectual property; and policies in the US, China, EU, Japan, and local jurisdictions. Fundamentals covered at an introductory level to support readings may include time value of money, economies of scale, social welfare analysis, externalities, valuation of reduced mortality risk; choice modeling, regression, life cycle assessment, optimization, game theory, and other topics. Fluency with algebra and calculus is assumed.

19-669 Behavior, Decision and Policy

Intermittent: 12 units

Behavioral science can inform policy making in three ways: (a) improving two-way communication between the public and policy makers; (b) creating policies that make realistic assumptions about human behavior; (c) disciplining the expert judgment needed to analyze risks. The course will introduce and discuss the technical and ethical foundations of behavioral research and risk analysis, setting them in their historical, social, and political context. It will apply them to a wide variety of technology-related policies, including energy (e.g., conservation, nuclear power), environment (e.g., climate, pollution), health (e.g., vaccines, COVID-19), national security (e.g., terrorism, intelligence analysis), and others, including ones proposed by students. Students will acquire a critical perspective on policies in their lives, society, and profession. The course is open to juniors, seniors, and graduate students, who have not taken 84369/84669.

19-670 Quantitative Entrepreneurship: Analysis for New Technology Commercialization

Spring: 12 units

This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design, manufacturing, and enterprise planning decisions for commercializing new technologies and products. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with multivariable calculus, linear algebra, and probability theory.

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5>)

19-671 Tech Start-up: Market Discovery

Spring: 6 units

The first three years of a technology start-up are the most critical; when the company's DNA or trajectory is set. Too few entrepreneurs appreciate this fact and, as a result, many start without the essential skills talents and capabilities needed to set the company on a successful path. Some of these entrepreneurial skills can only be learned through starting and growing a business while others can be learned. This course attempts to bridge the challenging gap between learning and doing entrepreneurship. We introduce you to an essential skill of market discovery or learning to create, develop and evaluate your concept of your business. Is my idea a real innovation? Is it also a business or a product or neither? How do I know how big the market is for my product? What are the technology market and competitive risks in my idea and how do I assess them? Can I compete? Can I sell it? How? When? Where? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies role-playing and solving actual problems of local tech businesses. The best way to learn entrepreneurship is by doing, which is why this course will use 'true-to-life' scenarios as the anchor for the course. The class will be divided into 4 teams will focus on a company that is either (1) a student idea for new start-up, (2) an existing start-up (ideally local) or (3) a hypothetical start-up proposed/conceived by the students, the professor or both

19-672 Special Topics: Tech Start-up: Building Your Own Company

Fall: 6 units

(Session 2) - The first year or two of a tech start-up set the trajectory and character of that company for years to come. Too few entrepreneurs appreciate this reality and, as a result, many carry forward misconceptions and misconceptions about creating and building a successful tech company that set it on the path for failure. This class attempts to remedy that challenge by exposing the student the practical reality of building a team and funding a start-up team. This class should help the student answer (or know how to find the answer) to the following questions: How do I find manage and evaluate a start-up team Do I have the skill motivation and ability to be a tech entrepreneur? Can I build a company from scratch (really)? Should I be the CEO Sales Account Manager VP of Engineering or something else altogether? How much money do I raise and where and when do I raise it? Students will have the opportunity to apply their newfound practical skills gathered in part from lectures from experienced entrepreneurs and investors to case studies.

19-680 E&TIM Seminar on Innovation Management in Practice

Intermittent: 6 units

Innovation has been described as "the intersection of invention and insight, leading to the creation of social and economic value." Companies increasingly rely on innovation to establish and drive their success. Public policy makers see innovation as a critical driver for economic development. This course is an opportunity to learn about innovation management from those in the front lines. How are innovation opportunities identified? What are the challenges to realizing these opportunities, and how can the challenges be addressed? What roles are played by processes, technologies and the business environment, as well as by individuals in organizations? This course will feature speakers who drive innovation in a variety of settings, paired with readings from the innovation literature that will help frame the presentations and discussion.

19-682 The Strategy and Management of Technological Innovation

Intermittent: 12 units

Strategy is distinctive approaches executives use to realize firm performance goals. In this course, we will prepare you for analyzing how technology and innovation affects how executives formulate and execute strategies. This course teaches how incorporating technology and innovation into the corporate strategy of the firm can achieve profitable and sustainable competitive advantage. It addresses the role of technology management in both emerging and established firms, and examines how all of the firm's activities, assets, and relationships must complement one another in order to capture value from innovation. The course will progress in two parts. We will first cover how strategy is formulated through frameworks, models, and tools essential for those actively engaged in the innovation process within a firm and apply these to case studies illustrating their importance in technology industries. We will then cover the obstacles that prevent firms from executing the ideal strategy. In each framework we analyze during the class, we will have the following objectives: 1) Recognizing the performance metric targeted by each framework 2) Identifying the assumptions each framework makes about firm structure, the speed of market and technological change 3) Analyze the strengths and weakness of each framework 4) Apply tools suited for each framework to determine the appropriate strategy that the firm should undertake 5) Using organizational theory to recognize obstacles that prevent the firm from implementing the desired strategies and how to overcome such barriers to implementation

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5>)

19-684 Engineering and Technology Innovation Management in Practice

Intermittent: 6 units

In this course, we will apply the fundamentals of innovation principles and practices to sponsored projects from corporations. You will work in teams to address the sponsors' objectives, using concepts such as six levers of innovation, seven innovation rules, design roadmapping, etc. Working closely with the sponsor is required so engaging in an appropriate professional manner is expected. Moreover, understanding how to approach team projects, manage team dynamics, and developing presentation skills will also be a part of the curriculum. The course is a culmination of utilizing your learnings from the ETIM program to address customers' needs.

19-685 Engineering Optimization without Project

Intermittent: 9 units

This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project

19-687 Managing Research, Development and Innovation

Intermittent: 6 units

This course considers key issues and trade-off in R and D strategy and organization, paying attention to dynamic competitive contexts where technology plays a key role. These topics are treated assuming the perspective of the decision maker. It addresses typical problems of large, medium and small firms having a structured R and D and operating businesses where R and D is the source of competitive advantages. Although we will heavily focus on R and D, emphasis is placed on viewing R and D as a part (although, a key part) of the process of technological innovation; therefore, as an activity to be strongly and appropriately integrated with other functions to make innovation successful.

19-689 Finance for Innovation Management

Intermittent: 6 units

In this course, there will be three main elements all focused around the innovation decision-making process: Basic financial concepts Business case development by innovation project managers. Tools and processes used in innovation decision-making With respect to financial concepts, the course will provide an introduction of the basic financial concepts that corporations use to capture their financial performance including the following: Basic financial statement information income statement / balance sheet / meanings / interpretations / analysis of financial statements/determination of cash flow / annual reports, etc. Performance metrics, ROI, Debt to Equity ratio, EPS, NOPAT, EBITDA, Liquidity, Days outstanding, other appropriate measures The intention of this introduction is to provide future project managers with a sufficient understanding of the financial information that is typically used in building a business case to make innovation decisions both in a corporate setting and in a more entrepreneurial setting. With respect to actual innovation decision-making, the course will examine the various tools and techniques that are used by (1) corporations to make investment decisions in specific R and D projects and (2) entrepreneurial organizations to make investments and R and D decisions in new technical projects. This course will address a number of commonly used decision tools such as: (1) Discounting / Net Present Value calculations (NPV), IRR / Payback Period / ROIC / etc.; (2) Decision and Risk Analysis methodologies; and (3) Portfolio management Finally, the course will develop an understanding of the differences between how corporations and how entrepreneurial firms use these tools, examine the implications of financial analysis techniques on R and D decision-making, and will examine some of the suggested fallacies and the limitations of financial analysis of innovation management.

19-690 M.S. Project

Fall and Spring

For E and D TIM and EPP MS students only, with faculty approval.

19-693 Managing and Leading Research and Development

Intermittent: 12 units

This course will provide an insider's look at issues in industrial research and development laboratories that future industrial R and D personnel are likely to face.

Course Website: <http://www.ece.cmu.edu/courses/items/18703.html>**19-694 Leadership and Innovation Management**

Fall: 6 units

The attributes and skills of the contributors to innovation are important elements in the effectiveness of the innovation process and the success of the outcome. In this course, we will focus on these skills and attributes, including diversity and inclusion, with an emphasis on the leaders of innovation and innovative organizations. Selected literature, case studies, and guest lectures by leaders, as well as the instructor's own experience as Carnegie Mellon's eighth president, will be the sources from which the course will draw. Students will gain insight into the roles they may play in contributing to and leading innovation and organizations and the skills and attributes they will need for success.

19-695 Internship Practicum

Summer

Experiential learning opportunities are important educational options for undergraduate and graduate students. One such option is an internship or practicum. If an internship is an explicit part of an academic program or is supervised by a faculty member, this course number may be used. Please consult the supervising faculty member concerning grading options and the appropriate number of units. NOTE: Special Permission required to register for this course

19-701 Introduction to the Theory and Practice of Policy Analysis

Intermittent: 12 units

This course reviews and critically examines a set of problems, assumptions and analytical techniques that are common to research and policy analysis in technology and public policy. Topics covered include the difference between science, trans-science and policy analysis, policy problems formulated in terms of utility maximization, issues in the valuation of intangibles, uncertainty in policy analysis, selected topics in risk analysis, limitations and alternatives to the paradigm of utility maximization, issues in behavioral decision theory, issues related to organizations and multiple agents, and selected topics in policy advice and policy analysis for the federal government. The objective is to look critically at the strengths, limitations and underlying assumptions of key policy research and analysis tools and problem framing and sensitize students to some of the critical issues of taste, professional responsibility, ethics, and values that are associated with policy analysis and research.

19-702 Quantitative Methods for Policy Analysis

Intermittent: 12 units

Economic framework for identifying and analyzing investment and operation options facing agencies and firms, (both in theory and in practice); economic efficiency, utilization, pricing, and investment; and multi-objective evaluation.

19-703 Applied Data Analysis 1

Intermittent: 6 units

Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.

19-704 Applied Data Analysis 2

Intermittent: 6 units

Students will gain a basic understanding of the estimation, interpretation, and diagnostic assessment of the most widely used statistical models in the social sciences. This includes: graphical and inferential statistics, multiple regression with interactions, logistic regression, multi-level models, and panel data. Assignments include six data analysis projects in R. 19703 is part 1, 19704 is part 2.

Prerequisite: 19-703

19-705 Workshop Applied Policy Analysis

Intermittent: 6 units

This workshop course is about learning how to structure messy un-structured policy problems. It is designed to provide experience in setting up, analyzing, and writing about policy problems of the type that are used in the EPP Part B qualifying exam. Over the course of the semester, the class works through six or seven policy case problems. Much of the work is done in small groups. The principal focus is on integrating the qualitative and quantitative aspects of the problems and on identifying and practicing general problem-solving strategies. Remote option is only with permission of instructor. Students are expected to attend in person.

19-707 Multiple Criteria Decision Making

Fall: 6 units

Problems with multiple, conflicting objectives are ubiquitous in the private and, especially, the public sector where tradeoffs among economic efficiency, equity and environmental quality are common. The objective of this course is to provide an overview of the techniques for the analysis and resolution of multiple criteria decision making (MCDM) problems. Topics will include multi-objective programming, multi-attribute utility theory and several MCDM methods such as the Analytical Hierarchy Process. The emphasis will be on theory and technique, but there will be several applications to demonstrate the methods. Undergraduate students require permission of the instructor to enroll.

19-711 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech

Fall: 12 units

Science and Innovation Leadership for the 21st Century introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors, seniors and graduate students.

19-713 Policies of Wireless Systems

Intermittent: 12 units

This course will address public policy issues related to wireless systems, and to the Internet. It begins by investigating policies related to a wide variety of emerging wireless systems and technologies, including wifi computer networks, broadband to the home, broadcast radio and television, and satellite communications. This can include the government role in facilitating the creation of infrastructure, in advancing competition among broadcasters and communications service providers, in managing spectrum, and in protecting privacy and security. The course will then address Internet policy issues, which can include Internet governance and the domain name system, taxation, privacy and security, and intellectual property. Because these are inherently interdisciplinary issues, the course will include detailed discussions of technology, economics, and law, with no prerequisites in any of these areas. Note: ECE students must take this course under #18-650 only

19-714 Environmental Life Cycle Assessment

Spring: 12 units

Cradle-to-grave analysis of new products, processes and policies is important to avoid undue environmental harm and achieve extended product responsibility. This course provides an overview of approaches and methods for life cycle assessment and for green design of typical products and processes using the ISO 14040 family of standards. This includes goal and scoping definition, inventory analysis, life cycle impact assessment (LCIA), interpretation, and guidance for decision support. Process-based analysis models, input-output and hybrid approaches are presented for life cycle assessment. Example software such as MATLAB, Excel, and Simapro are introduced and used in assignments. A group life cycle assessment project consistent with the principles and tools of sustainability to solve real-world engineering problems is required.

Prerequisites: (12-421 or 12-706) and 12-712

Course Website: <https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5> (<https://cmu.box.com/s/zjvqn8ne12sjwqmtvev2w49s78ij5sm5>)

19-717 Sustainable Engineering Principles

Fall: 12 units

This course presents an overview of the concept of sustainability, including changing attitudes and values toward technology and the environment through the late twentieth and early twenty-first centuries. Relevant issues in sustainable engineering, including population growth, urbanization, energy, water, food and material resources are discussed. Tools for sustainable engineering are presented, including metrics of sustainability, principles of design for the environment, and use of material and energy balances in sustainable systems. Publicly available data sets and computational models will be explored to assess sustainability. A team-based project is required.

19-726 Mathematical Modeling of Environmental Quality Systems

Spring: 12 units

Development and application of mathematical models for environmental systems. Material balance formulations and their solutions, computer implementation, model validation, uncertainty analysis, and use for projection and policy analysis. Applications to surface water, groundwater, atmospheric transport, indoor air pollution, and human exposure and risk. Prerequisite: 12-704

19-751 Air Quality Engineering

Intermittent: 12 units

The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines.

19-785 Engineering Optimization

Fall: 12 units

This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project

19-819 A/B Testing, Design, and Analysis

Spring: 6 units

This course looks at how to use A/B testing to measure causal effects in online platforms in the era of big data analytics. We aim at answering questions such as how does the demand for a product change when the price does or the ratings do? How can we anticipate how sales and profits change if the firm changes its business strategy? Facebook, Google, Amazon and similar firms ask and answer questions of this kind everyday using their large online platforms. This course introduces fundamental concepts to correctly ask this type of question. We study frameworks to measure causal effects and we discuss their pros and cons. Every tool is discussed in the context of a specific example that students work on using real world datasets. Significant effort is placed on understanding how to design randomized experiments (aka A/B tests) to measure causal effects. We also discuss the most common challenges that arise when trying to design such experiments in the wild and in network settings. The concepts and tools discussed in this course are general in nature and can be applied in settings other than online platforms such as energy, transportation and education. The examples in class will be mostly drawn from our own work at the Heinz College on the media industry. Lectures are 3 hours long. In the first half of each lecture we go over concepts behind A/B tests and what to do when A/B tests are unavailable. The discussion is based on the ideas and intuition behind these concepts. In the second half of each lecture we go over specific examples and #8212; we study the associated datasets and the code used to analyze them properly. Student evaluation is based on five weekly homeworks and a brief term project to be developed in teams. Instructor: Pedro Ferreira, www.andrew.cmu.edu/user/pedrof Pre-requisites: Knowledge of R or STATA. A class in statistics and regression analysis or permission of the instructor.

19-867 Decision Analytics for Business and Policy

Intermittent: 12 units

This course introduces modeling frameworks and computational tools to address complex, ill-defined, large-scale decision-making problems that arise in policy and business. Using a combination of lecturing, case studies and class discussions, it covers advanced methods of decision-making under uncertainty in four major areas: large-scale optimization, discrete event simulation, stochastic optimization and queuing theory. The application of such methods are drawn from a variety of real-world settings in a variety of domains such as transportation, energy, information systems, health care, supply chain management, etc. Participants are expected to take active learning roles in the computational application of the materials presented in class using the R programming language and the CPLEX optimization solver. A term project simulates realistic and challenging professional situations where new solutions need to be developed, implemented and communicated. The prerequisite is an introductory course in Operations Research, such as Management Science I and II or Decision-Making under Uncertainty. The learning objectives of this course fall into the following categories learning advanced quantitative modeling and solution algorithms from the fields of Operations Research and Management Science (OR/MS) applying OR/MS methods systematically to model complex decision-making problems faced in practice implementing simulation and optimization methods with large-scale datasets using state-of-the-art software evaluating the challenges and trade-offs in quantitative modeling and computation communicating technical models and results effectively based on the context and the audience

Prerequisites: 90-760 and 90-722 and 90-819

Department of Materials Science and Engineering

Elizabeth Dickey, Head
Location: Wean Hall 3327
materials.cmu.edu (<http://materials.cmu.edu>)

Materials Science & Engineering (MSE) is an engineering discipline that applies the tools of basic and applied sciences and engineering to the manufacture and application of materials and devices. The four broad classes of Materials to which this paradigm is applied are metals, polymers, ceramics, and composites. Essentially every technology (historical, modern, and future) depends on materials development and innovation.

The overarching paradigm of MSE is to determine and to exploit the connection between processing, structure, and properties of materials to engineer materials that fit the performance criteria for specific applications, which are useful for the technological needs of our society. In addition to this product specific knowledge, MSE is concerned with the implications of materials production and their sustainable use on the environment and energy resources.

Graduates of the MSE department are pursuing careers in an expanding spectrum of companies, national laboratories, and universities. Their activities cover a wide range of materials related endeavors that include microelectronics, energy production and storage, biomedical applications, aerospace, information technology, nanotechnology, manufacturing and materials production. Many of our undergraduate alumni choose to attend graduate school; they are accepted into the top Materials graduate schools in the country.

The standard curriculum of the department provides fundamental training for all materials science and engineering areas (see www.cmu.edu/engineering/materials/undergraduate_program/curriculum (http://www.cmu.edu/engineering/materials/undergraduate_program/curriculum/)). The core courses provide understanding and training on tools for working with the (atomic) structure of materials that governs their properties, the thermodynamic relationships that govern the stability of materials, and the rates at which changes take place in materials. Students complete their learning with a capstone design experience in the final year, which integrates their materials knowledge and training with engineering team skill development. To supplement the core course program, students may also participate in the current research programs of the faculty and conduct undergraduate research projects as part of their program of study.

While the core program is focused on the understanding of the internal or surface structure of materials in order to predict and engineer their properties, it is a flexible program that allows students to focus within a chosen material class, whether it is ceramics, semiconductors, metals, composites, magnetic or optical materials, bio-materials or polymers. The program also permits the option of cross concentration in the one or more of the areas of application such as electronic materials*, engineering design*, environmental engineering*, additive manufacturing*, mechanical behavior of materials*, biomedical engineering**, and engineering and public policy**, is also available. (*= Designated Minor, **= Additional Major). Our curriculum is designed to provide a strong foundation in fundamental knowledge and skills that provide an excellent base for our graduates planning to continue on to graduate studies. For our graduates who seek employment in industry, the program provides the foundation on which a graduate can build his/her domain specific knowledge. For students that develop or seek opportunities in other disciplines after graduation, the MSE curriculum provides a modern liberal education combined with the engineering rigors, i.e. one that inculcates upon a thoughtful, problem-solving approach to professional life. It is thus the goal of our education to provide a global and modern education in Materials Science and Engineering to support our graduates during their careers in materials industries or as a foundation for further studies in any of the leading global institutions of graduate education.

Accreditation

The BS program in Materials Science and Engineering is accredited by the Engineering Accreditation Commission of ABET, <https://www.abet.org>, under the General Criteria and the Program Criteria for Materials, Metallurgical, Ceramics and Similarly Named Engineering Programs.

Program Educational Objectives

Graduates with a B.S. degree from the Materials Science and Engineering program will, within a few years after graduation

- (1) attain success in a professional position and/or a top graduate school that builds upon their MSE background
- (2) exhibit professionalism and leadership in contemporary, interdisciplinary engineering practice based on materials, while accounting for the impact of their profession on an evolving, global society
- (3) contribute to innovative designs of technological systems using principles of materials science and engineering
- (4) make effective contributions as an individual, team member, and/or a leader to effect global, economic, environmental, and/or societal impact

Student Outcomes

1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
3. an ability to communicate effectively with a range of audiences
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Curriculum

Minimum units required for B.S. in Materials Science & Engineering 381

Standard Program

Freshman Year

| Fall | | Units |
|--------|---|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 27-100 | Engineering the Materials of the Future * | 12 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| xx-xxx | General Education Course | 9 |
| 33-141 | Physics I for Engineering Students | 12 |

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| Spring | | Units |
|--------|---|-------|
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Second Introductory Engineering Course | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 76-101 | Interpretation and Argument | 9 |

43

Sophomore Year

| | | Units |
|-----------|--|-----------|
| Fall | | |
| 27-201 | Structure of Materials | 9 |
| 27-210 | Materials Engineering Essentials | 6 |
| 27-215 | Thermodynamics of Materials | 12 |
| 09-105 | Introduction to Modern Chemistry I ** | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 15-110 | Principles of Computing | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 39-210 | Experiential Learning I | 0 |
| | | 58 |

| | | Units |
|--------|------------------------------|-----------|
| Spring | | |
| 27-202 | Defects in Materials | 9 |
| 27-216 | Transport in Materials | 9 |
| 27-217 | Phase Relations and Diagrams | 12 |
| 21-260 | Differential Equations | 9 |
| 39-220 | Experiential Learning II | 0 |
| xx-xxx | General Education Course | 9 |
| | | 48 |

Junior Year

| | | Units |
|-----------|---|-----------|
| Fall | | |
| 27-301 | Microstructure and Properties I | 9 |
| 27-xxx | MSE Restricted Elective [1] | 9 |
| xx-xxx | Free Elective [1] | 9 |
| 33-225 | Quantum Physics and Structure of Matter or | 9 |
| or 09-217 | Organic Chemistry I | |
| or 03-121 | Modern Biology | |
| xx-xxx | General Education Course | 9 |
| 39-310 | Experiential Learning III | 0 |
| | | 45 |

| | | Units |
|--------|--|-----------|
| Spring | | |
| 27-367 | Selection and Performance of Materials | 6 |
| 27-305 | Introduction to Materials Characterization | 6 |
| xx-xxx | General Education Course | 9 |
| 27-xxx | MSE Restricted Elective [2] | 9 |
| 27-xxx | MSE Restricted Elective [3] | 9 |
| xx-xxx | Free Elective [2] | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| | | 57 |

Senior Year

| | | Units |
|--------|-----------------------------|-----------|
| Fall | | |
| 27-401 | MSE Capstone Course I | 6 |
| 27-xxx | MSE Restricted Elective [4] | 9 |
| xx-xxx | Free Elective [3] | 9 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | General Education Course | 9 |
| | | 42 |

| | | Units |
|--------|---------------------------------|-----------|
| Spring | | |
| 27-402 | MSE Capstone Course II | 6 |
| 27-xxx | MSE Approved Technical Elective | 9 |
| xx-xxx | Free Elective [4] | 9 |
| xx-xxx | Free Elective [5] | 9 |
| xx-xxx | General Education Course | 9 |
| | | 42 |

* The Materials in Engineering course 27-100 may also be taken in the spring semester, and must be taken before the end of the sophomore year (the H&SS Elective in the Sophomore Spring may be moved to later in the program to accommodate the 27-100 course).

** These courses must be taken before the end of the sophomore year, but need not be taken in the same order or semester as listed above.

All mathematics (21-xxx) courses required for the engineering degree taken at Carnegie Mellon must have a minimum grade of C in order to be counted toward the graduation requirement for the BS engineering degree.

Notes on the Curriculum**Academic Advising**

Paige Houser is the academic advisor for all MSE students.

Quality Point Average

In addition to the College requirement of a minimum cumulative quality point average of 2.00 for all courses taken beyond the freshman year, the Department requires a quality point average of 2.00 or higher in courses taken in the MSE department. Students may repeat a course to achieve the QPA requirement. Only the higher grade will be used for this departmental calculation.

MSE Approved Technical Elective

Students are required to take at least 9 units of approved technical electives. Students may take a course from another CIT department to fulfill this requirement or choose an additional 9 units of MSE Restricted Electives. Courses on the exclusion list **cannot** be counted as a technical elective. Students who are pursuing an additional major or minor within CIT should check with their academic advisor regarding double counting of this course.

| Courses on this list cannot be counted as a technical elective | Units |
|--|-------|
| 06-426 Experimental Colloid Surface Science | 9 |
| 06-466 Experimental Polymer Science | 9 |
| 12-201 Geology | 9 |
| 18-202 Mathematical Foundations of Electrical Engineering | 12 |
| 18-300 Fundamentals of Electromagnetics | 12 |
| 24-311 Numerical Methods | 12 |
| 42-202 Physiology | 9 |
| 42-610 Introduction to Biomaterials | 9 |

MSE Restricted Electives

Each student in the program must take at least 36 units of MSE restricted electives. Up to 18 units of MSE research can count toward the restricted electives.

All 27-3xx, 27-4xx, 27-5xx, 27-6xx (with the exception of) and 27-7xx level and cross listed courses will fulfill the MSE Restricted Elective Requirement along with the following non-MSE courses:

| Non-MSE courses that count as restricted electives | Units |
|--|-------|
| 06-609 Physical Chemistry of Macromolecules | 9 |
| 09-509 Physical Chemistry of Macromolecules | 9 |
| 12-411 Project Management for Engineering and Construction | 9 |
| 12-631 Structural Design | 12 |
| 18-310 Fundamentals of Semiconductor Devices | 12 |
| 24-262 Mechanics II: 3D Design | 10 |
| 24-341 Manufacturing Sciences | 9 |

Integrated B.S./M.S. Program

Undergraduates who excel academically have the unique opportunity to receive simultaneously or sequentially both B.S. and M.S. degrees from the department. The primary purpose of the Integrated Master and Bachelor (IMB) Degree Program is to provide students with superior breadth and depth in technical material, which will better prepare them for careers in industry. Students interested in pursuing the IMB Degrees are encouraged to begin taking some of the required graduate courses before their last year. The MSE department offers two M.S. degrees: one in Materials Science and Engineering (MSE), a coursework degree, and one in Materials Science (MS), a coursework + research degree. The IMB Degree Program to obtain an M.S. in MSE (MS) degree normally requires two (three to four) additional full academic semesters of coursework (coursework + research) beyond the B.S. Degree Requirements (normally eight academic semesters). Experience has shown that students complete the IMB program in eight to ten full academic semesters after enrolling at CMU.

Degree Requirements

IMB students can be enrolled in either the M.S. in MSE (coursework) or the M.S. in MS (coursework + research) degree programs, depending on their preference.

Students must meet the requirements of either the M.S. in MSE or the M.S. in MS degree programs, as well as any specially stated rules below.

Eligibility

The IMB Program is available to all undergraduates who maintain a cumulative QPA of 3.0 or better, including the freshman year and the years in which they are enrolled in the IMB. Exceptions can be made by the Department on the basis of other factors, including extenuating (e.g., medical) circumstances, improvement in grades, strong recommendation letters, etc.

Students become eligible to apply to the program during the spring semester of their junior year (5th semester), or the semester in which they accumulate 280 or more units, whichever is earlier.

Enrollment

Students interested in the IMB program are not required to follow the formal application process for acceptance into the MSE graduate program. There is no requirement to provide a formal application, application fee, GRE scores, recommendation letters, official transcripts, or a statement of purpose. Interested students are encouraged request acceptance into the program by contacting the MSE academic advisor by email prior to the middle of the semester in which they become eligible.

Requirements to Enroll as a Graduate Student

If a student takes more than 8 semesters to complete both the B.S. and M.S. in MSE (coursework), then he or she must be a graduate student for at least one full-time 14-week academic semester (Fall or Spring) before graduating, whether or not they have already completed their B.S. degree.

Students should refer to the College of Engineering and University policies regarding enrollment status.

Tuition Assistance

When a student is a full-time graduate student through the IMB program, the department is able to provide some tuition assistance through optional Teaching Assistantships.

Faculty

CHRISTOPHER BETTINGER, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2010–

MICHAEL BOCKSTALLER, Professor – Ph.D., Max-Planck Institute for Polymer Research; Carnegie Mellon, 2005–

ITZHAQ COHEN-KARNI, Professor – Ph.D., Harvard University; Carnegie Mellon, 2013–

ELIZABETH C. DICKEY, Professor and Department Head – Ph.D., Northwestern University; Carnegie Mellon, 2021–

MARC DE GRAEF, Professor – Ph.D., Catholic University Leuven (Belgium); Carnegie Mellon, 1993–

ADAM FEINBERG, Professor – Ph.D., University of Florida; Carnegie Mellon, 2010–

ROBERT HEARD, Teaching Professor – Ph.D., University of Toronto; Carnegie Mellon, 2003–

MOHAMMAD F. ISLAM, Professor of Materials Science and Engineering – Ph.D., Lehigh University; Carnegie Mellon, 2005–

AMANDA R. KRAUSE, Assistant Professor – Ph.D., Brown University; Carnegie Mellon, 2022–

RACHEL KURCHIN, Assistant Research Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

NOA MAROM, Associate Professor – Ph.D., Weizmann Institute of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

THOMAS O'CONNOR, Assistant Professor – Ph.D., Johns Hopkins University; Carnegie Mellon, 2021–

P. CHRIS PISTORIUS, Professor and Associate Department Head – Ph.D., University of Cambridge; Carnegie Mellon, 2008–

LISA M. PORTER, Professor – Ph.D., North Carolina State; Carnegie Mellon, 1997–

GREGORY S. ROHRER, Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 1990–

ANTHONY D. ROLLETT, Professor – Ph.D., Drexel University; Carnegie Mellon, 1995–

PAUL A. SALVADOR, Professor and Executive Director of the Masters program in Energy Science, Technology and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1999–

MAREK SKOWRONSKI, Professor – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VINCENT SOKALSKI, Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

S. MOHADESEH TAHERI-MOUSAVIDI, Assistant Professor – Ph.D., Ecole Polytechnique Federale de Lausanne; Carnegie Mellon, 2022–

ELIAS TOWE, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2001–

BRYAN A. WEBLER, Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2013–

JAY WHITACRE, Professor – Ph.D., University of Michigan; Carnegie Mellon, 2007–

Affiliated Faculty

ROSALYN ABBOT, Assistant Professor of Biomedical Engineering – Ph.D., University of Vermont;

AMIT ACHARYA, Professor, Civil and Environmental Engineering – Ph.D., University of Illinois, Urbana-Champaign; Carnegie Mellon, 2000–

JAMES BAIN, Professor, Electrical and Computer Engineering – Ph.D., Stanford University; Carnegie Mellon, 1993–

JACK BEUTH, Professor, Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1992–

PHIL CAMPBELL, Research Professor, Institute for Complex Engineered Systems – Ph.D., The Pennsylvania State University; Carnegie Mellon, 2000–

KAUSHIK DAYAL, Professor of Civil and Environmental Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 2008–

MAARTEN DE BOER, Professor of Mechanical Engineering – Ph.D., University of Minnesota; Carnegie Mellon, 2007–

AMIR BARATI FARIMANI, Assistant Professor – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018–

RANDALL FEENSTRA, Professor, Physics – Ph.D., California Institute of Technology; Carnegie Mellon, 1995–

ERICA FUCHS, Professor – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2007–

STEPHEN GAROFF, Professor Emeritus, Physics – Ph.D., Harvard University; Carnegie Mellon, 1988–

REEJA JAYAN, Associate Professor, Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2015–

DAVID KINDERLEHRER, Professor, Mathematical Sciences – Ph.D., University of California, Berkeley; Carnegie Mellon, 1990–

JOHN KITCHIN, Professor of Chemical Engineering – Ph.D., University of Delaware; Carnegie Mellon, 2006–

TOMEK KOWALWESKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences; Carnegie Mellon, 2000–

SHAWN LITSTER, Professor, Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2008–

SARA MAJETICH, Professor, Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

CARMEL MAJIDI, Professor of Mechanical Engineering – Ph.D., University of California; Carnegie Mellon, 2011–

JONATHAN MALEN, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 2009–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner Professor of Natural Sciences, Department of Chemistry and Materials Science and Engineering – Ph.D., Polytechnical University of Łódź, Poland; Carnegie Mellon, 1985–

ALAN MCGAUGHEY, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2005–

SNEHA PRABHA NARRA, Assistant Professor, Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

O. BURAK OZDOGANLAR, Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

ROBERT SEKERKA, University Professor Emeritus, Physics, Mathematics and Materials Science – Ph.D., Harvard; Carnegie Mellon, 1969–

SHENG SHEN, Professor, Mechanical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

ROBERT SUTER, Professor Emeritus – Ph.D., Clark University; Carnegie Mellon University; Carnegie Mellon, 1978, 1981–

FATMA ZEYNEP TEMEL, Assistant Professor, Robotics Institute – Ph.D., Sabanci University; Carnegie Mellon, 2019–

ZACHARY ULISSI, Associate Professor, Chemical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon University; Carnegie Mellon, 2016–

NEWELL R. WASHBURN, Associate Professor of Chemistry, Biomedical Engineering and Materials Science and Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

LINING YAO, Assistant Professor of Human-Computer Interaction Institute and College of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–

JIAN-GANG ZHU, Professor, Electrical and Computer Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 1997–

Emeriti Faculty

ROBERT F. DAVIS, Professor Emeritus – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

WARREN M. GARRISON, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1984–

ANDREW GELLMAN, Professor Emeritus, Chemical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

DAVID E. LAUGHLIN, Professor Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1974–

PAUL WYNBLATT, Professor Emeritus of Materials Science and Engineering – Ph.D., University of California at Berkeley; Carnegie Mellon, 1981–

Adjunct Faculty

AHARON INSPEKTOR, Adjunct Faculty, Materials Science and Engineering – Ph.D., Technion Israel Institute of Technology; Carnegie Mellon, 2019–

Department of Materials Science and Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

27-052 Introduction to NanoScience and Technology

Summer: 9 units

This course is offered within Carnegie Mellon's Advanced Placement Early Admissions (APEA) program. The course is primarily intended to provide an introduction to nanoscience and technology to a wide audience of students at the advanced high school to incoming freshmen level. The course goals are twofold: (1) to provide students with a holistic view of the objectives, opportunities and challenges of the emerging field of nanotechnology and (2) to sensitize students at an early stage of their career to the relevance of the connections among the traditional disciplines as a vital element to the progress in interdisciplinary areas such as nanotechnology. The course will cover: Introduction and fundamental science; Preparation of nanostructures; Characterization of nanostructures; Application examples, Social and ethical aspects of nanotechnology. Admission according to APEA guidelines.

27-100 Engineering the Materials of the Future

Fall and Spring: 12 units

Materials form the foundation for all engineering applications. Advances in materials and their processing are driving all technologies, including the broad areas of nano-, bio-, energy, and electronic (information) technology. Performance requirements for future applications require that engineers continue to design both new structures and new processing methods in order to engineer materials having improved properties. Applications such as optical communication, tissue and bone replacement, fuel cells, and information storage, to name a few, exemplify areas where new materials are required to realize many of the envisioned future technologies. This course provides an introduction to how science and engineering can be exploited to design materials for many applications. The principles behind the design and exploitation of metals, ceramics, polymers, and composites are presented using examples from everyday life, as well as from existing, new, and future technologies. A series of laboratory experiments are used as a hands-on approach to illustrating modern practices used in the processing and characterization of materials and for understanding and improving materials' properties.

27-201 Structure of Materials

Fall: 9 units

This course covers the fundamentals of crystallography and diffraction. Topics covered include: the periodic table of the elements, bonding in different classes of materials, Bravais lattices, unit cells, directions and planes, crystal geometry computations, direct and reciprocal space, symmetry operations, point and space groups, nature of x-rays, scattering in periodic solids, Bragg's law, the structure factor, and the interpretation of experimental diffraction patterns. 24 crystal structure types of importance to various branches of materials science and engineering will be introduced. Amorphous materials, composites and polymers are also introduced. This course includes both lectures and laboratory exercises.

Prerequisite: 21-122 Min. grade C

27-202 Defects in Materials

Fall: 9 units

Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course, which includes classroom and laboratory sessions, is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.

Prerequisites: 27-201 or 27-215 or 21-122 Min. grade C or 21-120 Min. grade C

27-210 Materials Engineering Essentials

Fall: 6 units

This course approaches professional skill holistically, having materials science and engineering students understand that being a professional includes having competencies and responsibilities that are personal, organizational and professional.

Prerequisites: 21-122 Min. grade C or 21-120 Min. grade C

27-211 Structure of Materials (Minor Option)

Fall: 6 units

This course is identical to 27-201, but without the 3-unit lab component.

27-212 Defects in Materials (Minor Option)

Spring: 6 units

THIS IS FOR THE MSE MINOR ONLY: Defects have a fundamental influence on the properties of materials, including deformation, electrical, magnetic, optical, and chemical properties, as well as the rates of diffusion in solids. As such, by the controlling the population of intrinsic and extrinsic defects, one can tailor the properties of materials towards specific engineering applications. The objective of this course is to define approaches to quantifying the populations and properties of defects in crystals. The course will be divided into three sections: point defects, dislocations, and planar defects. The formation of point defects and their influence on diffusion, electrical, and magnetic properties will be considered. The properties and characteristics of dislocations and dislocation reactions will be presented, with a focus on the role of dislocations in deformation. The crystallography and energetics of planar defects and interfaces will also be described, with a focus on microstructural evolution at high temperatures. Time permitting, volume defects or other special topics are also discussed.

27-215 Thermodynamics of Materials

Fall: 12 units

The first half of the course will focus on the laws of thermodynamics and the inter-relations between heat, work and energy. The concept of an equilibrium state of a system will be introduced and conditions which must be satisfied for a system to be at equilibrium will be established and discussed and the concepts of activity and chemical potential introduced. The second half of the course will focus on chemical reactions, liquid and solid solutions, and relationships between the thermodynamics of solutions and binary phase diagrams.

27-216 Transport in Materials

Spring: 9 units

This course is designed to allow the student to become familiar with the fundamental principles of heat flow, fluid flow, mass transport and reaction kinetics. In addition, the student will develop the skills and methodologies necessary to apply these principles to problems related to materials manufacture and processing. Topics will include thermal conductivity, convection, heat transfer equations, an introduction to fluid phenomena viscosity, etc., Newtons and Stokes Laws, mass momentum balances in fluids, boundary layer theory, diffusion and absolute reaction rate theory. Where appropriate, examples will be taken from problems related to the design of components and the processing of materials.

Prerequisites: 27-210 and 27-215

27-217 Phase Relations and Diagrams

Spring: 12 units

Stability of structures. Hume-Rothery rules. Free energy-composition curves with applications to binary and ternary phase diagrams. Quantitative concepts of nucleation and growth with examples from solidification. Development of microstructures in various classes of phase diagram under near-equilibrium conditions. Atomic mechanisms of solid state diffusion and approach to equilibrium through diffusion.

Prerequisites: 27-201 and 27-215

27-227 Phase Relations and Diagrams (Minor Option)

Spring: 9 units

This course is identical to 27-217, but without the 3-unit lab component.

27-301 Microstructure and Properties I

Fall: 9 units

The objective of this course is to convey some of the essential concepts in materials science and engineering that relate properties (strength, toughness, formability, elasticity, magnetism, thermal expansion, for example) to the microstructure (crystal structure, dislocation structure, grain size, atoms in solids solution, precipitate characteristic, cellular materials). These relationships will be illustrated in terms of idealized materials and actual materials used in many applications. The course contains both lectures and laboratory exercises. The labs will include studies of recrystallization, the effect of microstructure on the properties of wood and the effect of microstructure on the mechanical behavior of a low alloy steel, 4140.

Prerequisites: 27-217 and 27-216

27-305 Introduction to Materials Characterization

Spring: 6 units

The course introduces the modern methods of materials characterization, including characterization of microstructure and microchemistry of materials. A classroom component of the course will introduce the wide array of methods and applications of characterization techniques. Basic theory will be introduced where needed. Students will then be instructed in the use of several instruments such as AFM, SEM, and EDS, using a hands-on approach. All instruments are part of the existing lab facilities within MSE and CIT. The methods learned in this course will serve the student during several other higher level courses, such as the Senior level MSE Capstone Course (27-401).

27-357 Introduction to Materials Selection

Spring: 6 units

In this course we follow the design-led approach to evaluate possible materials. In this approach, we start with a property (or combination of properties) which are relevant to a particular design, and then consider what classes of materials and what specific materials meet the design criteria. The logical path is hence from application to material. We shall give attention to materials fundamentals (such as grains and bonding) where these are relevant and useful to understanding differences between different materials - such as why the elastic modulus of steel cannot be changed by heat treatment or alloying, whereas the strength can be changed a great deal.

27-367 Selection and Performance of Materials

Spring: 6 units

This course teaches the selection methodologies for materials and processes for satisfaction of a design goal. Topics such as performance under load, shape effects, material properties (intrinsic and as influenced by processing) are discussed and applied so as to determine the fitness of use of materials for applications. Expanded topics include economics, codes and standards, environmental and safety regulations, professional ethics and life cycle analysis where applicable. The course incorporates a project where virtual teams work to provide material selection for a specific application problem.

Prerequisites: 27-301 and 27-100

27-401 MSE Capstone Course I

Fall: 6 units

This is the first of 2 course that together fulfill the Capstone requirement. This capstone course introduces the student to the methodology used for projects and teams based research as practiced in the Materials Science and Engineering workplace. This is a project course that requires the knowledge relationship among processing, structure, and performance to address an important contemporary problem in materials science and engineering. Student taking this course will work in a team environment to complete a design project to resolve scientific and engineering issues relating to materials. Research topics will be selected from a list of material problems or research concepts generated from companies or academia - industry research partnerships. This course will establish the research goals, review applicable research methodologies, introduce project management skills and discuss ethical concepts as teams assemble and set their research directions. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, sets out a methodology for the research, includes a literature review, and reports early experimentation results and provides recommendations for future work.

Prerequisites: 27-367 and (27-305 or 27-205) and 27-301

27-402 MSE Capstone Course II

Spring: 6 units

This is the spring extension of 27-401. Teams or team members that have the industry agreement and that wish to continue their research project may do so in this course. As with 27-401, all research is expected to be original, and proper scientific ethics, and methodologies are enforced for the research and reports. Team participation and communication is an important issue and the presentation and reports must be technical and professional in structure. The course requires full project management and accounting for the research being conducted. On the topic selected, the work product is a report that provides clear definition of the problem being addressed, a methodology for the research, literature review, experimentation and reporting of findings, conclusions based on findings, and recommendations for future work.

Prerequisite: 27-401

27-406 Sustainable Materials

Fall and Spring: 9 units

This course is intended to instill a sense of how materials properties and performance are conceived and brought to market specifically under sustainability constraints arising from the increasing demand of materials. Students will be introduced to the global nature of materials and will explore the global influences on the materials supply and value chains. The student will explore issues through the framework of the materials lifecycle including resource availability, manufacturing choices, and disposable options for materials in light of their use and selection for application. As a result, the student will be able to make more informed material selection or be able to use this information to identify critical research directions for future material development.

27-410 Computational Techniques in Engineering

Spring: 12 units

This course develops the methods to formulate basic engineering problems in a way that makes them amenable to computational/numerical analysis. The course will consist of three main modules: basic programming skills, discretization of ordinary and partial differential equations, and numerical methods. These modules are followed by two modules taken from a larger list: Monte Carlo-based methods, molecular dynamics methods, image analysis methods, and so on. Students will learn how to work with numerical libraries and how to compile and execute scientific code written in Fortran-90 and C++. Students will be required to work on a course project in which aspects from at least two course modules must be integrated.

Prerequisites: 21-120 and 21-122 and (15-122 or 15-112 or 15-110) and 21-260 and 21-259

27-421 Processing Design

Fall: 6 units

In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-432 Electronic and Thermal Properties of Metals, Semiconductors and Related Devices

Intermittent: 9 units

Fall odd years: This is Part I of a two-part course (Part II is 27-433) sequence concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part I will develop an in-depth understanding, based on the modern theories of solids, of the electrical, electronic and thermal properties of metals and semiconductors and the principles of operation of selected products and devices made from these materials. Overarching and interrelated topics will include elementary quantum and statistical mechanics, relationships between chemical bonds and energy bands in metals and semiconductors, the roles of phonons and electrons in the thermal conductivity of solids, diffusion and drift of electrons and holes, the important role of junctions in the establishment and control of electronic properties of selected metal- and semiconductor-based devices. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations. Additional topics will include microelectro-mechanical systems and nanoelectronics.

27-433 Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices

Intermittent: 9 units

Fall even years: 9 units This is Part II of a two-part course sequence (Part I is 27-432) concerned with the electrical, dielectric, magnetic and superconducting properties of materials. Students taking Part II will develop an in-depth understanding, based on the modern theories of solids, of the dielectric, magnetic and superconducting properties of materials and the principles of operation of selected products and devices made from these materials. Topics will include relationships between chemical bonds and energy bands in dielectric and magnetic materials; polarization mechanisms in materials and their relationship to capacitance, piezoelectricity, ferroelectricity, and pyroelectricity; magnetization and its classification among materials; magnetic domains; soft and hard magnets; and the origin, theory and application of superconductivity. Examples of commercial products will be introduced to demonstrate the application of the information presented in the text and reference books and class presentations.

27-445 Structure, Properties and Performance Relationships in Magnetic Materials

Spring: 9 units

This course introduces the student to intrinsic properties of magnetic materials including magnetic dipole moments, magnetization, exchange coupling, magnetic anisotropy and magnetostriction. This is followed by discussion of extrinsic properties including magnetic hysteresis, frequency dependent magnetic response and magnetic losses. This will serve as the basis for discussing phase relations and structure/properties relationships in various transition metal magnetic materials classes including iron, cobalt and nickel elemental magnets, iron-silicon, iron-nickel, iron-cobalt and iron platinum. This will be followed by a discussion of rare earth permanent magnets, magnetic oxides, amorphous and nanocomposite magnets. Polymers used in Electromagnetic Interference (EMI) Absorbers applications will also be covered.

27-454 Supervised Reading

Spring

This course provides the opportunity for a detailed study of the literature on some subject under the guidance of a faculty member, usually but not necessarily in preparation for the Capstone Course, 27-401/402.

27-477 Introduction to Polymer Science and Engineering

Spring: 9 units

This survey-level course introduces the fundamental properties of polymer materials and the principles underlying the synthesis, engineering, manufacturing, and design with polymer materials. Fundamental concepts of molecular interactions and structure formation in molecular materials will be introduced and the effect of chemical composition on physical properties of polymers will be discussed. The basic principles of polymer chemistry will be introduced and discussed in the context of step- and chain-growth reactions. This is followed by an introduction to technologically relevant engineering properties of polymer materials with focus on mechanical properties, concepts of viscoelasticity and their application to polymer product engineering, a survey of relevant forming technologies as well as the effect of processing on material performance. Case studies will introduce students to the various stages of technical product development, i.e. problem analysis, material selection and processing plan. A final section will discuss polymer recycling and sustainable polymer technologies for a circular economy.

Prerequisite: 27-215

27-503 Additive Manufacturing and Materials

All Semesters: 9 units

This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-505 Exploration of Everyday Materials

Spring: 9 units

This course is developed for upper level undergraduate and master level students outside of the College of Engineering that wish to learn about materials by experientially exploring a material and or an application of a material. Each year the course will select a material that through its' application, presents and opportunity or a concern in service. It will engage the students with studio-based exploration of the material and application, the selection criteria applicable, and engineering principles that influence the performance. It will explore a wide range of influential topics constraining material selection including societal concerns about materials and global sustainability.

27-514 Bio-nanotechnology: Principles and Applications

Spring: 9 units

"Have you ever wondered what is nanoscience and nanotechnology and their impact on our lives? In this class we will go through the key concepts related to synthesis (including growth methodologies and characterizations techniques) and chemical/physical properties of nanomaterials from zero-dimensional (0D) materials such as nanoparticles or quantum dots (QDs), one-dimensional materials such as nanowires and nanotubes to two-dimensional materials such as graphene. The students will then survey a range of biological applications of nanomaterials through problem-oriented discussions, with the goal of developing design strategies based on basic understanding of nanoscience. Examples include, but are not limited to, biomedical applications such as nanosensors for DNA and protein detection, nanodevices for bioelectrical interfaces, nanomaterials as building blocks in tissue engineering and drug delivery, and nanomaterials in cancer therapy."

27-515 Introduction to Computational Materials Science

Fall: 9 units

This course introduces students to the theory and practice of computational materials science from the electronic to the microstructural scale. Both the underlying physical models and their implementation as computational algorithms will be discussed. Topics will include: Density functional theory Molecular dynamics Monte Carlo methods Phase field models Cellular automata Data science Coursework will utilize both software packages and purpose-built computer codes. Students should be comfortable writing, compiling, and running simple computer programs in C, C++, Fortran, MatLab, Python, or comparable environment. THIS COURSE IS FOR MSE UNDERGRADUATE STUDENTS ONLY.

27-520 Tissue Engineering

Spring: 12 units

This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

27-533 Principles of Growth and Processing of Semiconductors

Fall: 6 units

Development of a fundamental understanding of material principles governing the growth and processing of semiconductors. Techniques to grow and characterize bulk crystals and epitaxial layers are considered. The processing of semiconductors into devices and the defects introduced thereby are discussed. The roles of growth- and processing-induced defects in determining long term reliability of devices are examined.

27-537 Data Analytics and Machine Learning for Materials Science

Spring: 9 units

Materials Science and Engineering has traditionally been taught by emphasizing the development and application of technology. This course will present an alternative approach that combines data mining, data analytics, and material fundamentals (i.e. materials informatics). Students will be introduced to informatics techniques related to data mining and large database analysis. The topics will include: ¥ Principal Component Analysis (PCA) ¥ Canonical Correlation Analysis (CCA) ¥ Neural Networks ¥ Machine Learning ¥ Computer Vision There will be a project in which students will apply appropriate techniques to a data set of their choosing. Students should be comfortable writing, compiling, and running simple computer programs in MatLab, Python, R, or comparable environment. Prerequisites: 36-220 or 19-250

27-542 Thin Film Technologies

Fall: 9 units

This course will provide you with an understanding of the general science and technology involved in the production of solid thin films, the characteristics of thin film growth processes, methods to characterize important properties of thin films, and some of their current applications, particularly with regard to alternative energy sources, energy-efficient technologies and biosensing technologies. The class will include hands-on experience with thin film production, characterization and device fabrication (and characterization).

27-555 Materials Project I

Fall

This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing.

27-556 Materials Project II

Spring

Second semester of Materials Project. This course is designed to give experience in individualized research under the guidance of a faculty member. The topic is selected by mutual agreement, and will give the student a chance to study the literature, design experiments, interpret the results and present the conclusions orally and in writing.

27-561 Kinetics of Metallurgical Reactions and Processes

Fall: 6 units

This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-565 Nanostructured Materials

Intermittent: 9 units

This course is an introduction to nanostructured materials or nanomaterials. Nanomaterials are objects with sizes larger than the atomic or molecular length scales but smaller than microstructures with at least one dimension in the range of 1-100 nm. The physical and chemical properties of these materials are often distinctively different from bulk materials. For example, gold nanoparticles with diameters ~15 nm are red and ~40 nm gold nanoparticles are purple whereas bulk gold has a golden color. The course starts with a discussion of top-down and bottom-up fabrication methods for making nanostructures as well as how to image and characterize nanomaterials including scanning probe microscopies. Emerging nanomaterials such as fullerenes, graphene, carbon nanotubes, quantum dots and nanocomposites are also discussed. The course then focuses on applications of nanomaterials to microelectronics, particularly nanoscale devices and the emerging field of molecular-scale electronics. The miniaturization of integrated systems that sense mechanical or chemical changes and produce an electrical signal is presented. The principles and applications of the quantum confinement effects on optical properties are discussed, mainly as sensors. The last part of the course is a discussion of nanoscale mechanisms in biomimetic systems and how these phenomena are applied in new technologies including molecular motors.

27-570 Polymeric Biomaterials

Spring: 12 units

This course will cover aspects of polymeric biomaterials in medicine from molecular principles to device scale design and fabrication. Topics include the chemistry, characterization, and processing of synthetic polymeric materials; cell-biomaterials interactions including interfacial phenomena, tissue responses, and biodegradation mechanisms; aspects of polymeric micro-systems design and fabrication for applications in medical devices. Recent advances in these topics will also be discussed.

27-577 Advanced Polymer Science and Engineering

Fall: 9 units

This advanced-level course introduces the physical concepts necessary to understand the structure-processing-properties relationships of polymers in the solid state. Chain models fundamental to the description of polymers will be introduced. The structure of solid-state polymers will be discussed with focus on the amorphous, crystalline and liquid-crystalline state. The glass transition in amorphous polymers as well as the morphology and kinetics of crystal formation in semi-crystalline polymers will be discussed in detail. Mechanical properties of polymers will be discussed with emphasis of network elasticity and linear viscoelastic behavior. Models to describe nonlinear deformation will be introduced. Simplified and viscoelastic flow models as well as the solidification of polymers will be discussed and their relevance to polymer processing illustrated. Anisotropy development during processing and the application of symmetry concepts to deduce microstructure in processed parts will be discussed. A final section of the class will be dedicated to polymer blends. Basic concepts of lattice models will be introduced and applied to predict the phase behavior of polymer blends. Applications of polymer blends, including thermoplastic elastomers and rubber toughening will be discussed.

Prerequisite: 27-477

27-591 Mechanical Behavior of Materials

Intermittent: 9 units

Spring odd years: Fundamentals of stress and strain. Linear elastic behavior. Tensile testing and yield criteria. Relationships between stress and strain for the case of plastic deformation. Theoretical strength. Tensile tests of single crystals and the idea of a slip system. Shear stress versus shear strain curves for single crystals and the effects of crystal orientation, temperature, atoms in solid solution and precipitates on the shapes of such curves. Taylor's connection between tensile curves of single crystals and those of polycrystalline samples. Dislocations and plastic deformation. Strengthening mechanisms including solid-solution strengthening, strengthening by precipitates, work hardening and grain size effects on strength. Approaches to quantifying the fracture resistance of materials, including the Griffith approach, the energy release rate approach and the stress intensity factor approach. Crack tip behavior including stresses and strains at crack tips and the plastic zone. Fracture mechanisms including ductile fracture, cleavage fracture and intergranular fracture. The fracture of highly brittle materials. Time permitting fatigue and creep of materials will be discussed.

27-592 Solidification Processing

Intermittent: 9 units

Spring odd years: The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-700 Energy Storage Materials and Systems

Fall and Spring: 12 units

Contemporary energy needs require energy storage and conversion for a range of mobile and stationary applications. This course will examine electrochemically functional materials, devices, and systems that are used to convert, store, and release electrical energy. The principles and mathematical models of electrochemical energy conversion and storage will be examined in depth; students will study thermodynamics and reaction kinetics pertaining to electrochemical reactions, phase transformations, transport, and processing relating to a wide range of related technologies. This course also will cover the practical aspects associated with the application of batteries, fuel cells, supercapacitor technologies. Students are asked to conduct a class project that involves interacting with outside industry and culminates in a end-of-semester poster session.

27-703 Additive Manufacturing and Materials

All Semesters: 12 units

This course will develop the understanding required for materials science and engineering for additive manufacturing. The emphasis will be on powder bed machines for printing metal parts, reflecting the research emphasis at CMU. The full scope of methods in use, however, will also be covered. The topics are intended to enable students to understand which materials are feasible for 3D printing. Accordingly, high power density welding methods such as electron beam and laser welding will be discussed, along with the characteristic defects. Since metal powders are a key input, powder-making methods will be discussed. Components once printed must satisfy various property requirements hence microstructure-property relationships will be discussed because the microstructures that emerge from the inherently high cooling rates differ strongly from conventional materials. Defect structures are important to performance and therefore inspection. Porosity is a particularly important feature of 3D printed metals and its occurrence depends strongly on the input materials and on the processing conditions. The impact of data science on this area offers many possibilities such as the automatic recognition of materials origin and history. Finally the context for the course will be discussed, i.e. the rapidly growing penetration of the technology and its anticipated impact on manufacturing.

27-704 Principles of Surface Engineering and Industrial Coatings

Fall and Spring: 6 units

Many modern technologies rely on the use of innovative, multi-functional coatings to ensure competitive advantage in the fast-changing global markets. Building such coatings requires advanced planning of the entire coating-substrate system, and of the manufacturing steps. This course will discuss the design principles of multi-functional coatings, present advanced coating architectures and review the relevant manufacturing steps. The course will be illustrated with design principles of functional coatings in three major industries: aerospace, automotive, and machining. We will identify the relevant key challenges, and follow the thinking process of the industry leaders addressing the challenge. Then, we will examine the developed coating solutions: multi-functional tribological coatings on cutting tools; thermal barrier coatings on nickel alloy turbine blades for aircraft and power generation; diamond like coatings and wear protective coatings for automotive diesel engines; and corrosion protection in the aerospace and in the automotive industries. The course will conclude with a discussion of new trends in surface engineering and in the design of multi-functional coatings, including self-healing, self-cleaning, and other smart coatings.

27-706 Hard and Superhard Materials

Fall and Spring: 6 units

This course will focus on the fundamental principles of hard and superhard materials. We will first discuss the origin of hardness across materials, and then describe important examples of materials prized for their intrinsic or extrinsic hardness. We will focus on the preparation, microstructure, and properties of materials such as diamond, cubic boron nitride and compound carbides. Then, we will emphasize the design of novel nano-structured and nano-composite materials and coatings, which are at the frontier of material science. Finally, the course will present examples of the architecture and processing methods used to generate hard materials and coatings in manufacturing automotive and aerospace industries.

27-709 Engineering Biomaterials

Fall: 12 units

This course will cover structure-processing-property relationships in biomaterials for use in medicine. This course will focus on a variety of materials including natural biopolymers, synthetic polymers, and soft materials with additional treatment of metals and ceramics. Topics include considerations in molecular design of biomaterials, understanding cellular aspects of tissue-biomaterials interactions, and the application of bulk and surface properties in the design of medical devices. This course will discuss practical applications of these materials in drug delivery, tissue engineering, biosensors, and other biomedical technologies.

27-715 Applied Magnetism and Magnetic Materials

Spring: 12 units

In this course we address the physics of magnetism of solids with emphasis on magnetic material properties and phenomena which are useful in various applications. The content of this course includes the origins of magnetism at the atomic level and the origins of magnetic ordering (ferro-, ferri-, and antiferromagnetism), magnetic anisotropy, magnetic domains, domain wall, spin dynamics, and transport at the crystalline level. The principles of magnetic crystal symmetry are utilized to explore the various domains in ferromagnetic crystals, and tensors are used in the description of such magnetic properties as magnetocrystalline anisotropy, susceptibility and magnetostriction. To a limited extent, the applications of magnetism are discussed in order to motivate the understanding of the physical properties and phenomena.

27-719 Computational Thermodynamics

Spring: 6 units

Computational thermodynamics is a powerful tool of a Materials Engineer. We will examine how thermodynamic simulation software outputs an equilibrium calculation from a list of input conditions. This requires a description of Gibbs energy minimization calculations, Gibbs energy models, and the construction of these models from thermodynamic data. At the end of the class students should be able to use thermodynamic simulation software to solve engineering problems while recognizing its limitations. This class is for graduate students interested in these computational tools.

27-720 Tissue Engineering

Spring: 12 units

This course will train students in advanced cellular and tissue engineering methods that apply physical, mechanical and chemical manipulation of materials in order to direct cell and tissue function. Students will learn the techniques and equipment of bench research including cell culture, immunofluorescent imaging, soft lithography, variable stiffness substrates, application/measurement of forces and other methods. Students will integrate classroom lectures and lab skills by applying the scientific method to develop a unique project while working in a team environment, keeping a detailed lab notebook and meeting mandated milestones. Emphasis will be placed on developing the written and oral communication skills required of the professional scientist. The class will culminate with a poster presentation session based on class projects. Pre-requisite: Knowledge in cell biology and biomaterials, or permission of instructor

27-721 Processing Design

Fall: 6 units

In this course, the concepts of materials and process design are developed, integrating the relevant fundamental phenomena in a case study of a process design. The course includes basic science and engineering as well as economic and environmental considerations. The case study is on environmentally acceptable sustainable steelmaking. Other case studies in materials processing could be used.

27-729 Solid State Devices for Energy Conversion

Intermittent: 6 units

Intensive research efforts have yielded promising new materials approaches to 'alternative' energy conversion technologies, such as solar cells or photovoltaics; thermoelectric materials, which convert waste heat to electricity; metal/semiconductor superlattices for thermionic energy conversion; and fuel cells. At the same time, notable advances have been made in devices that substantially enhance our energy efficiency: e.g., chemical sensors and light-emitting diodes for solid-state lighting. In all of these devices, interfaces between dissimilar materials often govern and/or limit the behavior. In addition to the basic structures and operating principles, this course will cover practical materials interface issues, such as electrical transport, thermal stability, contact resistance, and bandgap engineering, that significantly affect the performance of a variety of energy conversion and energy-saving devices.

27-731 Texture, Microstructure & Anisotropy

Intermittent: 6 units

The purpose of Texture, Microstructure and Anisotropy is to acquaint the student with a selected set of characterization tools relevant to the quantification of microstructure (including crystallographic orientation, i.e. texture) and anisotropic properties. The motivation for the course is problem solving in the areas of property measurement (e.g. grain boundary energy), prediction of microstructural evolution (e.g. in grain growth and recrystallization), and prediction of properties based on measured microstructure (e.g. anisotropy of work hardening and ductility). In this 6 unit mini version of the course, the specific objectives are to develop skills and understanding in the following areas: (1) The mathematical basis for crystallographic orientation distributions (aka ODFs), with explanations of the many representations of rotations/orientations; (2) Crystallographic preferred orientation (texture) and its representation by pole figures, inverse pole figures and orientation distributions, with a particular emphasis on the effects of symmetry in representations; (3) Methods of measuring texture such as X-ray (diffraction) Pole Figures and Electron Back Scatter Diffraction (EBSD) with reference to orientation mapping; (4) The effect of texture on elastic and plastic anisotropy in polycrystals; the uniform stress model (Sachs), the Taylor-Bishop and Hill model, the Eshelby analysis; Emphasis is placed on the use and understanding of quantitative tools for texture data acquisition and analysis (e.g. orientation distribution determination from pole figure data, and automated electron back-scatter diffraction/EBSD/OIM), the effect of crystal and sample symmetry on distributions and their representation, and the prediction of anisotropy (e.g. calculation of yield surfaces for plastic deformation). Since the datasets are often large, such as from EBSD scans, computer programs are essential.

27-734 Methods of Computational Materials Science

Fall: 12 units

This course introduces students to the theory and practice of computational materials science from the electronic to the microstructural scale. Both the underlying physical models and their implementation as computational algorithms will be discussed. Topics will include: Density functional theory Molecular dynamics Monte Carlo methods Phase field models Cellular automata Data science Examples and homework problems will be taken from all areas of materials science. Coursework will utilize both software packages and purpose-built computer codes. Students should be comfortable writing, compiling, and running simple computer programs in MatLab, Python, or comparable environment.

27-737 Data Analytics and Machine Learning for Materials Science

Intermittent: 12 units

Materials Science and Engineering has traditionally been taught by emphasizing the development and application of technology. This course will present an alternative approach that combines data mining, data analytics, and material fundamentals (i.e. materials informatics). Students will be introduced to informatics techniques related to data mining and large database analysis. The topics will include: Principal Component Analysis (PCA) Canonical Correlation Analysis (CCA) Neural Networks Machine Learning Computer Vision There will be two projects in which students will apply appropriate techniques to data sets of their choosing; in the second (graduate level) project, students will be asked to build, train, and execute a multi-layer neural net to automatically recognize shapes that are relevant to material microstructures. One quarter of the lectures in this course will focus on the custom creation of convolutional neural networks. Students should be comfortable writing, compiling, and running simple computer programs in MatLab, Python, R, or comparable environment.

27-741 Practical Methods in Transmission Electron Microscopy

Fall and Spring

This course is designed to provide instrument training on transmission electron microscopes in the Materials Characterization Facility (MCF). Emphasis will be placed on acquiring the basic skills needed to successfully operate this type of microscope; this will be achieved by a combination of lectures and hands-on lab sessions. Lectures will provide the necessary background to understand electron scattering techniques, including electron diffraction, bright field and dark field imaging, phase contrast microscopy, and energy dispersive x-ray spectroscopy. Lab sessions will inform the student on standard operating procedures for the techniques discussed in the lecture portion of the course. At the end of the course, the student is expected to demonstrate the ability to independently use the transmission electron microscope for basic operations; successful demonstration of such skills will lead to certification for day-use of transmission electron microscopes in the MCF.

27-752 Fundamentals of Semiconductors and Nanostructures

Spring: 12 units

This course is designed to provide students with a foundation of the physics required to understand nanometer-scale structures and to expose them to different aspects of on-going research in nanoscience and nanotechnology. Illustrative examples will be drawn from the area of semiconductor nanostructures, including their applications in novel and next-generation electronic, photonic, and sensing devices. The course begins with a review of basic concepts in quantum physics (wave-particle duality, Schr and Dirac's equation, particle-in-a-box, approximation methods in quantum mechanics, etc.) and then continues with a discussion of bulk three-dimensional solids (band structure, density of states, the single-electron effective-mass approximation). Size effects due to nanometer-scale spatial localization are then discussed within a quantum-confinement model in one-, two-, and three- dimensions for electrons. An analogous discussion for photons is also presented. The basic electronic, optical, and mechanical properties of the low-dimensional nanostructures are then discussed. A select number of applications in electronics, photonics, biology, chemistry, and bio-engineering will be discussed to illustrate the range of utility of nanostructures. Upon completion of the course, students will have an appreciation and an understanding of some of the fundamental concepts in nanoscience and nanotechnology. The course is suitable for first-year graduate students in engineering and science (but advanced undergraduates with appropriate backgrounds may also take it with permission from the instructor). Pre-requisites include 09-511, 09-701, 09-702, 18-311, 27-770, 33-225, 33-234 or familiarity with the material or basic concepts covered in these courses.

27-754 Mechanical Behavior of Engineering Materials

Intermittent: 12 units

Engineers employ all classes of materials (metals, polymers, ceramics and hybrids) in load-bearing applications. To reduce material cost, save energy and maximize performance, engineering materials are frequently designed to be used near their load-bearing limits. An understanding of underlying deformation mechanisms complements a design rule approach in that unexpected failures can be far better anticipated and hence minimized. This course will survey the major deformation mechanisms in the main materials classes. Topics will include structure, elasticity, continuum failure models, fracture mechanics, and plastic deformation mechanisms of polymers, fiber-reinforced, composites, ceramics and metals. Proper design practice and real-life failures will be discussed.

27-761 Kinetics of Metallurgical Reactions and Processes

Fall: 6 units

This class uses examples from the ironmaking and steelmaking to illustrate different rate-determining reaction steps. Reaction times in ironmaking and steelmaking process vary quite widely; the fundamental origins of the large differences in reaction time are analyzed, after a brief overview of the main reactions and process steps in ironmaking and steelmaking. Particular skills to be practiced and developed include derivation of the mathematical relationships which describe the rates of metallurgical processes which involve heat transfer, and mass transfer for solid-gas, liquid-gas and liquid-liquid reactions; quantifying the expected rates of such reactions; identification of rate-determining steps, based on calculated rates and observed reaction rates; predicting the effects of process parameters such as particle size, stirring, temperature and chemical compositions of phases on the overall rate; and critical evaluation of kinetic data and models in scientific papers on metallurgical reactions.

27-766 Defects and Diffusion in Materials

Fall: 12 units

Defects in materials, and the transport of matter through these defects by diffusion, strongly influence a material's physical properties and microstructural evolution. For example, the strength of materials, the electrical and optical properties of materials, and the rates at which microstructures coarsen, recrystallize, and oxidize all depend on the population of intrinsic and extrinsic defects and the transport of matter through these defects. The objective of this course is to define methods of quantifying the population and properties of defects in materials and the transport of matter through these defects. The course addresses both crystalline, semicrystalline, and amorphous materials and begins with the fundamentals of diffusion in amorphous materials. After describing point defect formation and equilibrium defect populations in elements and compounds, diffusion through these defects will be described. Point defect diffusion will be illustrated using examples such as the Kirkendall effect and diffusive creep. The properties and characteristics of dislocations, their motion, and the role of dislocations in deformation will also be discussed. Short circuit diffusion and the role of diffusion in dislocation creep will be described as examples of transport involving dislocations. Finally, the energetics of planar defects, grain boundaries, and interfaces will be discussed. Diffusive transport along interfaces will be described, using examples including transport in two phase systems, sintering, and coarsening.

27-791 Mechanical Behavior of Materials

Spring: 12 units

The intent of the course is to introduce various measures indicative of the performance of materials in applications. Properties often used in selecting materials will be introduced, and connections between these properties and microstructure will be developed. Mechanical properties are emphasized in this course. 4 hrs. lec.

27-792 Solidification Processing

Spring: 12 units

The goal of this course is to enable the student to solve practical solidification processing problems through the application of solidification theory. The objectives of this course are to: (1) Develop solidification theory so that the student can understand predict solidification structure; (2) Develop a strong understanding of the role of heat transfer in castings; (3) Develop an appreciation for the strengths and weaknesses of a variety of casting processes. The first half of the course will be theoretical, covering nucleation, growth, instability, solidification microstructure: cells, dendrites, eutectic and peritectic structures, solute redistribution, inclusion formation and separation, defects and heat transfer problems. The second part of the course will be process oriented and will include conventional and near net shape casting, investment casting, rapid solidification and spray casting where the emphasis will be on process design to avoid defects.

27-796 Structure and Characterization of Materials

Fall: 12 units

The objective of this course is for the student to be able to understand important crystal structures of both inorganic and organic materials in terms of their building blocks (atom positions, Bravais lattices, structural units, symmetry groups, stacking and packing configurations) and also to understand how modern experimental materials characterization techniques (including x-ray, electron, and neutron diffraction and spectroscopic techniques) are used to obtain structural and chemical information.

27-798 Thermodynamics of Materials

Fall: 12 units

This course offers a practical introduction to the principles of statistical thermodynamics that links the microscopic atomic details of materials to their macroscopic behavior, and applies these principles to multicomponent material equilibria. The laws and concepts of classical thermodynamics and probability are briefly reviewed, and then applied to introduce the atomic statistical definitions for temperature, entropy, and thermodynamic equilibrium. Statistical methods for enumerating the microscopic configurations of fluids, magnets, solid crystals, and polymers will be covered and applied to evaluate thermodynamic free energies subject to varying macroscopic constraints. These will be used to relate equilibrium properties and phase behavior to the engineerable molecular details of materials. Applications will include equilibrium phase diagrams (binary and ternary), predominance diagrams, chemical reactions, thermodynamics of surfaces, and electrochemistry.

27-990 SPECIAL TOPICS: Teaching Materials Science & Engineering

Spring: 3 units

This course is designed to prepare graduate students for their future role as educators in Materials Science and amp; Engineering. Teaching is a critical facet of higher education whether as a course assistant, instructor, or student mentor. Although excellent teaching can have a significant positive impact on students at all levels, formal training at the University level is relatively uncommon. Contrary to popular belief, teaching is not simply a skill you are born with, but rather one that requires significant practice and continuous refinement. The primary goal of this course is to provide pedagogical strategies necessary to be an effective teacher with a focus on fundamental topics in materials science and amp; engineering.

Department of Mechanical Engineering

Jonathan Cagan,
Department Head and George Tallman and Florence Barrett Ladd Professor
in Engineering

Location: Scaife Hall 336
www.cmu.edu/me (<http://www.cmu.edu/me/>)

General Overview

Mechanical engineers use their knowledge of mechanical systems to describe phenomena, propose solutions to problems, and build those solutions. Concerned with the principles of force, energy and motion, they use their knowledge of physical systems, design, manufacture, and operational processes to advance the world around us. Mechanical engineers work in a variety of sectors: small start-up companies, multi-national corporations, government agencies, national laboratories, consulting firms, and universities.

The Carnegie Mellon Mechanical Engineering curriculum emphasizes engineering theory, hands-on experience, and technical skills. Our students learn how to solve practical problems and analyze situations by converting ideas into reliable and cost-effective devices and processes.

A strong foundation in mechanical engineering fundamentals culminates in a design capstone class where student teams develop prototypes for new products. These projects expose students to the design process, from concept to product, and emphasize effective communication and presentations skills.

Our curriculum is intended to allow ample opportunity for students to pursue areas of personal interest. A student may choose to pursue a minor offered by departments in other colleges, or one of the designated minor programs offered in the College of Engineering, or to pursue an additional major. Students are encouraged to participate in research with department faculty members, explore their chosen field through internships, and take advantage of opportunities to study abroad and be exposed to other cultures. Students may also choose to pursue the Integrated Master's/Bachelor's Program (IMB) which allows students to earn both a bachelor's and a master's degree with an additional semester or year of study.

Mechanical Engineering students access TechSpark (<https://engineering.cmu.edu/techspark/>) for hands-on projects in multiple core courses and technical electives. TechSpark (<https://engineering.cmu.edu/techspark/>) is the cornerstone of the College of Engineering's maker ecosystem, where students are advised by faculty and staff to create, develop, and test new ideas for technology innovation. The space houses a computer simulation cluster, 3D printers, laser machines, electronics stations, manual & CNC mills, metal welding, wood working & CNC Router, polymer composite fabrication, paint booth, and more. This integrated set of resources allows students, faculty, and staff to design and prototype in a multi-disciplinary environment.

Accreditation

The Mechanical Engineering Undergraduate Program is accredited by the Engineering Accreditation Commission of ABET, www.abet.org (<http://www.abet.org>).

Educational Objectives

According to ABET (<http://www.abet.org/>), which evaluates applied science, computing, engineering and technology programs for accreditation, "program educational objectives are broad statements that describe what graduates are expected to attain within a few years of graduation."

The core objective of our undergraduate program is to provide our students an education that enables them to be productive, impactful, and fulfilled professionals throughout their careers. In light of this vision, the objectives of the Bachelor of Science in Mechanical Engineering at Carnegie Mellon are to produce graduates who:

- Distinguish themselves as effective problem solvers by applying fundamentals of mechanical engineering alongside modern experimental and computational methods
- Are innovative and resourceful in their professional activities.
- Excel in team settings, incorporating diverse viewpoints and ideas and implementing strategies for equitable participation

- Become effective communicators who are prepared to take on leadership roles in their organizations, their profession, and in society
- Conduct themselves in a professional and ethical manner in the workplace.
- Excel in diverse career paths within and beyond engineering profession, including in industry and academia.

Educational Outcomes

The undergraduate curriculum in the Department of Mechanical Engineering offers students significant opportunities to pursue directions of personal interest, including minors, double majors, participation in research projects, and study abroad. Design and teamwork experiences occur at regular intervals in the curriculum, and graduates have significant hands-on experience through laboratories and projects.

Carnegie Mellon's Mechanical Engineering faculty members are in support of the following set of skills and outcomes put forth by ABET:

- an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics
- an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors
- an ability to communicate effectively with a range of audiences
- an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts
- an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives
- an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions
- an ability to acquire and apply new knowledge as needed, using appropriate learning strategies

Curriculum

Minimum units required for B.S. in Mechanical Engineering: 382

The following template outlines the four-year B.S. program through the standard and recommended course sequence. To ensure that prerequisites are completed and to prevent scheduling conflicts, students should discuss any changes to this sequence with their department academic advisor. Students need a minimum of 382 units to complete the B.S. degree. Since there are variable units for some core requirements, additional units can be made up with free electives.

First Year

| Fall | | Units |
|--------|--|-----------|
| 21-120 | Differential and Integral Calculus | 10 |
| 24-101 | Fundamentals of Mechanical Engineering | 12 |
| 33-141 | Physics I for Engineering Students | 12 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| | | 46 |

| Spring | | Units |
|--------|--|--------------|
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Second Introductory Engineering Course | 12 |
| xx-xxx | Physics II/Computer Science/Chemistry* | 10-12 |
| xx-xxx | General Education Course | 9 |
| | | 41-43 |

First Year Curriculum Notes:

1. During the first year, students complete 24-101 Fundamentals of Mechanical Engineering and one other introductory engineering course. 24-101 Fundamentals of Mechanical Engineering is a prerequisite for sophomore courses 24-261 Mechanics I: 2D Design and 24-251 Electronics for Sensing and Actuation, as well

as junior course 24-351 Dynamics. Students who are not able to take 24-101 in their first year will push the 24-261 Mechanics I and 24-262 Mechanics II sequence into their junior year. If 24-101 is taken in fall of sophomore year, students can take 24-251 Electronics for Sensing and Actuation and 24-351 Dynamics in sophomore spring to continue progress towards the Mechanical Engineering degree.

2. All Mathematics courses (21-xxx) required for the engineering degree must have a minimum grade of C in order to fulfill the graduation requirement for the BS engineering degree and to count as a prerequisite for engineering core classes.
3. Students must pass the following three courses before they begin the core Mechanical Engineering courses in the fall of their sophomore year:
 - 21-120 Differential and Integral Calculus
 - 21-122 Integration and Approximation
 - 33-141 Physics I for Engineering Students

Sophomore Year

| Fall | | Units |
|--------|--|-------|
| 24-221 | Thermodynamics | 10 |
| 24-261 | Mechanics I: 2D Design | 10 |
| 21-260 | Differential Equations | 9 |
| xx-xxx | Physics II/Computer Science/Chemistry* | 10-12 |
| 24-xxx | 24-200 Machine Shop OR 24-251 Electronics for Sensing and Actuation ** and *** | 1-3 |
| xx-xxx | General Education Course | 9 |
| 39-210 | Experiential Learning I | 0 |

49-53

| Spring | | Units |
|--------|--|-------|
| 24-231 | Fluid Mechanics | 10 |
| 24-262 | Mechanics II: 3D Design | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| xx-xxx | Physics II/Computer Science/Chemistry* | 10-12 |
| 24-xxx | 24-200 Machine Shop OR 24-251 Electronics for Sensing and Actuation **and*** | 1-3 |
| xx-xxx | Lab requirement **** | |
| xx-xxx | General Education Course | 9 |
| 39-220 | Experiential Learning II | 0 |

51-55

- * **Physics II/Chemistry/Computer Science:**
 First year students are encouraged to prioritize completing Physics II and Programming requirement over Chemistry in the first year.
- The recommended Physics sequence is 33-141 (<http://coursecatalog.web.cmu.edu/search/?P=33-141>) / 33-142 (<http://coursecatalog.web.cmu.edu/search/?P=33-142>) for engineering students, however, 33-151 (<http://coursecatalog.web.cmu.edu/search/?P=33-151>) / 33-152 (<http://coursecatalog.web.cmu.edu/search/?P=33-152>) will also meet the CIT Physics requirement.
 - The programming requirement can be filled with 15-110 Principles of Computing or 15-112 Fundamentals of Programming and Computer Science.
 - The Chemistry requirement can be filled with 09-105 Introduction to Modern Chemistry I or 09-111 Nanolegogs: Chemical Building Blocks.

- ** **24-200 and 24-251 Completed Sophomore Year:**
 Machine shop 24-200 Maker Series: Intro to Manual Machining and 24-251 Electronics for Sensing and Actuation should be completed in sophomore year. Both are required courses.

- *** **Waiving Electronics for Sensing and Actuation:**
 Mechanical Engineering (MechE) students who took the 18-100 Introduction to Electrical and Computer Engineering in their first year, have the option of waiving 24-251 Electronics for Sensing and Actuation. These units must be replaced with 3 units of graded Mechanical Engineering credit which could be done by taking a 12 unit MechE Technical Elective instead of a 9 unit course. Eligible students will be invited to complete a form to confirm their intention to waive 24-251.

- **** **Lab Requirement:**
 Mechanical engineering undergraduates must satisfy one science laboratory requirement to graduate. The lab requirement may be fulfilled with one of the following courses in any semester:

| | | |
|--------|--|---|
| 03-124 | Modern Biology Laboratory | 9 |
| 09-101 | Introduction to Experimental Chemistry | 3 |

| | | |
|--------|-----------------------------------|---|
| 33-100 | Basic Experimental Physics | 6 |
| 33-104 | Experimental Physics | 9 |
| 42-203 | Biomedical Engineering Laboratory | 9 |

Junior Year

| Fall | | Units |
|--------|---|-------|
| 24-302 | Professional Development for Mechanical Engineers Taken either Fall or Spring. | 2 |
| 24-322 | Heat Transfer | 10 |
| 24-351 | Dynamics (Offered Fall and Spring) | 10 |
| | | 12 |
| 24-370 | Mechanical Design: Methods and Applications | 12 |
| xx-xxx | Engineering Statistics Requirement | 9 |

Students are required to complete an engineering statistics course. The department strongly encourages students to take 36-225 Introduction to Probability Theory, 36-219 Probability Theory and Random Processes or 36-220 Engineering Statistics and Quality Control will also fulfill the requirement.

| | | |
|--------|---------------------------|---|
| xx-xxx | General Education Course | 9 |
| 39-310 | Experiential Learning III | 0 |

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| Spring | | Units |
|--------|---|-------|
| 24-302 | Professional Development for Mechanical Engineers Taken either Fall or Spring. | 2 |
| 24-311 | Numerical Methods | 10 |
| 24-321 | Thermal-Fluids Experimentation | 12 |
| 24-352 | Dynamic Systems and Controls (Offered Fall and Spring) | 12 |
| xx-xxx | General Education Course | 9 |

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Senior Year

| Fall | | Units |
|--------|---|-------|
| 24-441 | Product Design **** | 12 |
| | or 24-671 Electromechanical Systems Design | |
| | or 24-631 Thermal Design | |
| 24-452 | Mechanical Systems Experimentation (Offered Fall and Spring) | 9 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 9 |
| xx-xxx | General Education Course | 9 |

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| Spring | | Units |
|--------|--|-------|
| 24-441 | Product Design **** | 12 |
| | or 24-671 Electromechanical Systems Design | |
| | or 24-631 Thermal Design | |
| 24-xxx | Mechanical Engineering Technical Elective | 9-12 |
| xx-xxx | General Education Course | 9 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 9 |

48-51

**** **Capstone Courses:**

- Mechanical Engineering students complete **one** capstone class either fall or spring of senior year. This course is the culmination of the knowledge gained over the previous years in mechanical engineering core classes. To fulfill the capstone course requirement, students can complete one of the following 24-441 Product Design (FALL OR SPRING), 24-671 Electromechanical Systems Design (FALL OR SPRING), or 24-631 Thermal Design (SPRING ONLY).
- Capstone course can be taken either Fall or Spring of senior year, with the exception of 24-631 Thermal Design (SPRING ONLY).

- Biomedical Engineering and Robotics Double Majors **may** use the capstone for their double major **instead of** the above listed MechE capstone classes.

Mechanical Engineering Technical Electives

Students must take at least one approved non-core Mechanical Engineering course labeled as "Mechanical Engineering Technical Elective" in the example course sequence. The course must be an approved 24-xxx course (9-unit minimum) at the 300 level or above to fulfill the technical elective requirement. 24-291 Environmental Systems on a Changing Planet and 24-292 Renewable Energy Engineering are the only 200 level courses that may be used as a Mechanical Engineering Technical Elective.

Students can also take mechanical engineering graduate courses to fulfill the technical elective requirement. However, students must have the appropriate prerequisites and the instructor must approve taking the course. Undergraduates do not have priority for graduate level courses. Students can find a list of graduate courses we offer on the Carnegie Mellon Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>).

Course offerings are variable, please check the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) to see the most current list of classes.

Students cannot use research or project courses to fulfill the technical elective requirement. However, these courses, with limitations, will count as free elective units. Up to 27 units of project/research may be counted in the free electives. Project/research courses that do not fulfill the technical elective requirements are:

- 24-391 / 24-392 Mechanical Engineering Project
- 24-491 / 24-492 Department Research Honors
- 39-xxx CIT series courses

Free Electives

A Free Elective is defined as any graded course offered by any academic unit of the university. Free electives offer students the opportunity to add additional majors and minors, pursue additional interests or deepen their experience in Mechanical Engineering. Typically, once the core requirements are completed, there remain about 45 units of free electives to reach the minimum of 382 to complete the degree.

Up to 9 units of Student Taught Courses (StuCO) and Physical Education courses, or other courses taken as Pass/Fail, may also be used toward Free Electives.

Guidance on Engineering Electives

The Mechanical Engineering department offers several elective courses for undergraduates seeking further knowledge and experience in specialty areas of mechanical engineering. These courses (with approval) can fulfill for your Mechanical Engineering Technical Elective, Free Electives, and/or additional major or minor requirements.

Robotics and Automation

Fundamental Courses

| | | |
|--------|--|----|
| 24-356 | Introduction to Vibrations with Applications | 9 |
| 24-451 | Feedback Control Systems | 12 |
| 24-677 | Modern Control Theory | 12 |
| 24-760 | Robot Dynamics and Analysis | 12 |
| 24-773 | Multivariable Linear Control | 12 |
| 24-776 | Non Linear Control | 12 |

Application Courses

| | | |
|--------|--|----|
| 24-614 | Microelectromechanical Systems | 12 |
| 24-671 | Electromechanical Systems Design | 12 |
| 24-673 | Soft Robots: Mechanics, Design and Modeling | 12 |
| 24-753 | Special Topics: Robotic Materials: Designs, Principles & Mechanics | 12 |
| 24-774 | Advanced Control Systems Integration | 12 |
| 24-775 | Special Topics: Robot Design and Experimentation | 12 |
| 24-778 | Mechatronic Design | 12 |

Energy, Environment, and Thermal Fluid Systems

Fundamental Courses

| | | |
|--------|------------------------------|----|
| 24-711 | Fluid Dynamics | 12 |
| 24-718 | Computational Fluid Dynamics | 12 |
| 24-721 | Advanced Thermodynamics | 12 |
| 24-722 | Energy System Modeling | 12 |
| 24-730 | Advanced Heat Transfer | 12 |

Application Courses

| | | |
|--------|--|----|
| 24-292 | Renewable Energy Engineering | 9 |
| 24-421 | Internal Combustion Engines | 12 |
| 24-425 | Combustion and Air Pollution Control | 9 |
| 24-428 | Computational Analysis of Transport Phenomena | 9 |
| 24-623 | Molecular Simulation of Materials | 12 |
| 24-626 | Air Quality Engineering | 12 |
| 24-628 | Energy Transport and Conversion at the Nanoscale | 12 |
| 24-629 | Direct Solar and Thermal Energy Conversion | 12 |
| 24-631 | Thermal Design | 12 |
| 24-643 | Energy Storage Materials and Systems | 12 |

Product Design and Development

Fundamental Courses

| | | |
|--------|---|----|
| 24-651 | Material Selection for Mechanical Engineers | 12 |
| 24-681 | Computer-Aided Design | 12 |
| 24-683 | Design for Manufacture and the Environment | 12 |
| 24-688 | Introduction to CAD and CAE Tools | 12 |

Application Courses

| | | |
|--------|---|----|
| 24-632 | Special Topics: Additive Manufacturing Processing and Product Development | 12 |
| 24-633 | Additive Manufacturing Laboratory | 12 |
| 24-672 | Special Topics in DIY Design and Fabrication | 12 |
| 24-680 | Quantitative Entrepreneurship: Analysis for New Technology Commercialization | 12 |
| 24-682 | Special Topics: Design for the Fourth Industrial Revolution | 12 |
| 24-687 | Grand Challenge Innovation | 12 |
| 24-691 | Mechanical Engineering Project Management | 12 |
| 24-692 | Special Topics: Engineering a Startup: How to Start and Grow a Hardware Company | 12 |

Autonomous Systems and Machine Learning

Fundamental Courses

| | | |
|--------|--|----|
| 24-451 | Feedback Control Systems | 12 |
| 24-480 | Special Topics: Artificial Intelligence and Machine Learning for Engineering | 9 |
| 24-677 | Modern Control Theory | 12 |
| 24-704 | Probability and Estimation Methods for Engineering Systems | 12 |
| 24-786 | Special Topics: Bayesian Machine Learning for Scientists and Engineers | 12 |
| 24-787 | Machine Learning and Artificial Intelligence for Engineers | 12 |
| 24-789 | Special Topics: Deep Learning for Engineers | 12 |

Application Courses

| | | |
|--------|--|----|
| 24-774 | Advanced Control Systems Integration | 12 |
| 24-775 | Special Topics: Robot Design and Experimentation | 12 |
| 24-784 | Special Topics: Trustworthy AI | 12 |

Computational Engineering

Fundamental Courses

| | | |
|--------|----------------------------------|----|
| 24-703 | Numerical Methods in Engineering | 12 |
| 24-780 | Engineering Computation | 12 |
| 24-783 | Advanced Engineering Computation | 12 |
| 24-785 | Engineering Optimization | 12 |

Application Courses

| | | |
|--------|---|----|
| 24-658 | Image-Based Computational Modeling and Analysis | 12 |
| 24-681 | Computer-Aided Design | 12 |

| | | |
|--------|---------------------------------|----|
| 24-718 | Computational Fluid Dynamics | 12 |
| 24-755 | Finite Elements in Mechanics I | 12 |
| 24-781 | Engineering Computation Project | 12 |

Engineering Mechanisms and Materials

Fundamental Courses

| | | |
|--------|---|----|
| 24-634 | Structural Design | 12 |
| 24-635 | Structural Analysis | 9 |
| 24-652 | Mechanical Behavior of Engineering Materials | 12 |
| 24-653 | Special Topics: Materials and Their Processing for Mechanical Engineers | 12 |
| 24-751 | Introduction to Solid Mechanics I | 12 |

Application Courses

| | | |
|--------|---|----|
| 24-643 | Energy Storage Materials and Systems | 12 |
| 24-650 | Applied Finite Element Analysis | 12 |
| 24-684 | Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology | 12 |
| 24-755 | Finite Elements in Mechanics I | 12 |
| 24-753 | Special Topics: Robotic Materials: Designs, Principles & Mechanics | 12 |

Quality Point Average Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. The Mechanical Engineering Department requires that students attain a quality point average of 2.00 or higher for all required Mechanical Engineering core courses.

Pursuant to university rules, students can repeat a course in which a grade below C was attained in order to achieve the QPA requirement. When a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. For all required Mechanical Engineering core courses, the highest grade obtained between the original and the repeated class will be used to calculate the Mechanical Engineering QPA.

Credit Overload Policy

Mechanical Engineering students can register for a maximum of 54 units per semester. A student can request additional units from the Undergraduate Education Committee based on their QPA. The policy is outlined in the Mechanical Engineering Undergraduate Handbook (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/undergraduate-handbooks.html>).

Double Majors and Minors

Mechanical Engineering students may pursue double majors and minors in a variety of subjects, taking advantage of the free elective courses to satisfy the requirements for the major or minor. The College of Engineering has added designated minors to promote flexibility and diversity among engineering students. Common double majors for Mechanical Engineering students include Engineering and Public Policy, Biomedical Engineering, Engineering Design, Innovation & Entrepreneurship and Robotics.

A complete description of majors and minors in engineering can be found on the College of Engineering website (<https://engineering.cmu.edu/education/undergraduate-programs/curriculum/majors-minors.html>).

Internships and Co-operative Education Program

The Mechanical Engineering Department considers experiential learning opportunities important educational options for its undergraduate students. Students in Mechanical Engineering are encouraged to undertake professional internships during summer breaks.

Another option is cooperative education, which provides a student with an extended period of exposure with a company. All co-ops must be at least 6

consecutive months in length, and must be a full-time, paid position with a single company.

Study Abroad

In today's global society, a study abroad experience can be an integral part of an undergraduate engineering education. An academic experience abroad is encouraged and assistance is provided for course choices and curriculum sequencing. The Mechanical Engineering department offers scholarships for international experiences to support and encourage students to take advantage of study and work abroad experiences.

Integrated Master's/Bachelor's Program (IMB)

Interested undergraduates may plan a course of study that leads to both the Bachelor's and Master's in Mechanical Engineering. Beyond eight semesters, at least one semester of full-time graduate student status is required. Please refer to the Integrated Master's/Bachelor's Degree Program section in the most recent Master of Science in Mechanical Engineering Handbook (<https://www.meche.engineering.cmu.edu/education/graduate-programs/handbooks.html>) for additional information.

Full-Time Faculty

AMIR BARATI FARIMANI, Assistant Professor of Mechanical Engineering - Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2018-

MARK BEDILLION, Teaching Professor of Mechanical Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016-

SARAH BERGBREITER, Professor of Mechanical Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 2018-

JACK LEE BEUTH, Professor of Mechanical Engineering - Ph.D., Harvard University; Carnegie Mellon, 1992-

JONATHAN CAGAN, Department Head and George Tallman and Florence Barrett Ladd Professor of Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 1990-

MAARTEN P. DE BOER, Professor of Mechanical Engineering - Ph.D., University of Minnesota; Carnegie Mellon, 2007-

NESTOR GOMEZ, Assistant Teaching Professor - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018-

NOELIA GRANDE GUTIERREZ, Assistant Professor of Mechanical Engineering - Ph.D., Stanford University; Carnegie Mellon, 2021-

DIANA HAIDAR, Assistant Teaching Professor of Mechanical Engineering - Ph.D., University of Delaware; Carnegie Mellon, 2017-

ENI HALILAJ, Assistant Professor of Mechanical Engineering - Ph.D., Brown University; Carnegie Mellon, 2018-

B. REEJA JAYAN, Associate Professor of Mechanical Engineering - Ph.D., University of Texas at Austin; Carnegie Mellon, 2015-

AARON M. JOHNSON, Assistant Professor of Mechanical Engineering - Ph.D., University of Pennsylvania; Carnegie Mellon, 2016-

TREVOR J JONES, Assistant Professor - Ph.D., Princeton University; Carnegie Mellon, 2023-

LEVENT BURAK KARA, Professor of Mechanical Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2007-

PHILIP R. LEDUC, William J. Brown Professor of Mechanical Engineering - Ph.D., The Johns Hopkins University; Carnegie Mellon, 2002-

SHAWN LITSTER, Professor of Mechanical Engineering - Ph.D., Stanford University; Carnegie Mellon, 2008-

CARMEL MAJIDI, Clarence H. Adamson Professor of Mechanical Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 2011-

JONATHAN A. MALEN, Professor of Mechanical Engineering - Ph.D., University of California at Berkeley; Carnegie Mellon, 2009-

CHRISTOPHER MCCOMB, Associate Professor of Mechanical Engineering - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021-

ALAN J.H. MCGAUGHEY, Trustee Professor of Mechanical Engineering - Ph.D., University of Michigan; Carnegie Mellon, 2005-

JEREMY J. MICHALEK, Professor of Mechanical Engineering - Ph.D., University of Michigan; Carnegie Mellon, 2005-

O. BURAK OZDOGANLAR, Ver Planck Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2004–

RAHUL PANAT, Russell V. Trader Career Development Associate Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2017–

SNEHA PRABHA NARRA, Assistant Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–

ALBERT PRESTO, Research Professor of Mechanical Engineering – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–

YOED RABIN, Professor of Mechanical Engineering – D.Sc., Technion-Israel Institute of Technology; Carnegie Mellon, 2000–

SHENG SHEN, Professor of Mechanical Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2011–

KENJI SHIMADA, Theodore Ahrens Professor of Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1996–

SATBIR SINGH, Teaching Professor of Mechanical Engineering – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 2012–

PAUL S. STEIF, Associate Department Head and Professor of Mechanical Engineering – Ph.D., Harvard University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Professor of Mechanical Engineering – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

REBECCA TAYLOR, Associate Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2016–

CONRAD TUCKER, Arthur Hamerschlag Career Development Professor of Mechanical Engineering – Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2019–

DOUGLAS WEBER, Akhtar and Bhutta Professor of Mechanical Engineering – Ph.D., Arizona State University; Carnegie Mellon, 2020–

VICTORIA WEBSTER-WOOD, Assistant Professor of Mechanical Engineering – Ph.D., Case Western Reserve University; Carnegie Mellon, 2018–

KATE S. WHITEFOOT, Associate Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2016–

JESSICA ZHANG, George Tallman Ladd and Florence Barrett Ladd Professor of Mechanical Engineering – Ph.D., University of Texas at Austin; Carnegie Mellon, 2007–

DING ZHAO, Assistant Professor of Mechanical Engineering – Ph.D., University of Michigan; Carnegie Mellon, 2018–

Emeriti

ADNAN AKAY, Lord Emeritus Professor of Mechanical Engineering – Ph.D., North Carolina State University; Carnegie Mellon, 1992–

JERRY HOWARD GRIFFIN, William J. Brown Emeritus Professor of Mechanical Engineering – Ph.D., California Institute of Technology; Carnegie Mellon, 1981–

WILFRED THOMAS ROULEAU, Emeritus Professor of Mechanical Engineering – Ph.D., Carnegie Institute of Technology; Carnegie Mellon, 1954–

EDWARD STEPHAN RUBIN, Emeritus Professor of EPP, Mechanical Engineering, and Environmental Engineering and Science – Ph.D., Stanford University; Carnegie Mellon, 1969–

SHI-CHUNE YAO, Emeritus Professor of Mechanical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 1977–

Department of Mechanical Engineering Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

24-050 Study Abroad

Fall
Mechanical Engineering students studying abroad through other institutions are registered for this zero-unit place holder "course." Prior to being enrolled for study abroad, the student must have completed an Office of International Education "Study Abroad Transfer Credit (SATC) Form," which must be signed by their academic advisor in Mechanical Engineering.

24-101 Fundamentals of Mechanical Engineering

Fall and Spring: 12 units
The purpose of this course is to introduce the student to the field of mechanical engineering through an exposition of its disciplines, including structural analysis, mechanism design, fluid flows, and thermal systems. By using principles and methods of analysis developed in lectures, students will complete two major projects. These projects will begin with conceptualization, proceed with the analysis of candidate designs, and culminate in the construction and testing of a prototype. The creative process will be encouraged throughout. The course is intended primarily for CIT first year students.

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-104 Maker Series: Intro to Modern Making

Fall and Spring: 3 units
This course teaches the safe operation of fabrication tools, including 3D printer, laser cutter-engraver machine, and soldering through structured hands-on activities. A significant portion of the course is dedicated to learning SolidWorks 3D CAD software and Arduino microcontroller for integrating physical computing into prototypes. The acquisition of these skills culminates in the development and fabrication of a prototype that solves a real-world problem. 3-unit mini (7-weeks)

Course Website: <http://www.cmu.edu/me> (<http://www.cmu.edu/me/>)

24-105 Special Topics: Maker Series: Intro to Laser Cutting & Engraving

Fall and Spring: 1 unit
This course teaches the safe operation of the laser cutter-engraver machine through structured hands-on activities. A significant portion of this course is dedicated to learning joinery, color mapping, and material selection for prototyping. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)

24-200 Maker Series: Intro to Manual Machining

Fall and Spring: 1 unit
This course teaches safe operation of manual machining equipment through structured hands-on activities. A significant portion of the course is dedicated to learning subtractive manufacturing, the industrial standard for the mass manufacture of products around the world. The skills learned in this course can be applied to fabricate durable components for design projects, research equipment, and extracurricular activities. 1-unit mini (7-weeks)

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-202 Introduction to Computer Aided Design

Fall and Spring: 1 unit
Introduction to computer aided mechanical design using SolidWorks 3D CAD software. Includes the creation and analysis of components and assemblies, generation of drawings, and exporting for manufacture. Two hours of guided computer lab work each week. Prerequisite: Undergraduate Mechanical Engineering standing
Prerequisites: 24-101 or 24-104

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-203 Special Topics: Maker Series: Intro to Manual & CNC Machining

Fall and Spring: 3 units
This course teaches safe operation of manual and CNC machining equipment. A focus of this course will be developing design-build skills for prototyping. A significant portion of the course is dedicated to learning CAM programming and PCB design software for rapid fabrication of 2D and 3D parts. The skills learned in this course can be applied to quickly fabricate durable components for design projects, research equipment, and extracurricular activities.

24-204 Special Topics: Maker Series: Intro to Metal Jewelry

Fall and Spring: 3 units
This course teaches introductory level metal jewelry fabrication. Students will learn to safely use various tools and metal working techniques including cold forging, investment casting, bezel settings, soldering, and patinas. These will be taught in class and reinforced by homework through structured activities to create their own personal jewelry, such as earrings, pendants, and rings. Upon completion of this class, students will be familiar with the Metals Room in TechSpark, and will be have access to the facility for future use. Materials fee will be required. Spaces are limited. 3-unit Mini (6 weeks).

24-205 Special Topics: Maker Series: Intro to Welding

Fall and Spring: 2 units
This course teaches the safe operation of MIG welding equipment through structured hands-on activities. A significant portion of the course is dedicated to learning workpiece setup, material selection, and quality assessment for building structures. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects.

24-206 Special Topics: Maker Series: Intro to Wood Working

Fall and Spring: 3 units
This course teaches the safe operation of wood working equipment, including table saw, panel saw, and miter saw through structured hands-on activities. A significant portion of the course is dedicated to learning optimal workflow, tool selection, and equipment selection for building structures. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects.

24-207 Special Topics: Maker Series: Intro to CNC Router

Fall and Spring: 1 unit
This course teaches the safe operation of a CNC router machine through structured hands-on activities. A significant portion of the course is dedicated to software for fabrication of 2D and 3D parts. Homework assignments are important for reinforcement of skills learned, and are flexible for students to complete guided or self-directed projects. 1-unit micro (2-weeks)
Prerequisite: 24-206

24-210 Special Topics: Maker Series: Inventive Projects

Fall and Spring
This course supports students in pursuing a self-defined project. Students will apply their preexisting access to equipment towards prototyping an inventive project, either as an individual or a group member. Students will receive weekly one-on-one consultations with the instructor to conduct project planning, design for fabrication, prototype testing, and more. This course is useful for students interested in initiating, progressing, and/or completing a prototyping project for research, student orgs, entrepreneurship, hobbies, or other interests.
Prerequisites: 24-101 or 24-206 or 24-205 or 24-204 or 24-200 or 24-105 or 24-104

24-212 Special Topics: Maker Series: Make It Move

Fall and Spring: 9 units

This course explores many types of mechanisms for movement and their optimal applications. A significant portion of class will be dedicated to hands-on labs, during which objects are dissected to reveal their methods of movement. Springs, gears, motors, pneumatics, levers, wheels, bearings, and other components will be analyzed for their roles in energy storage, power delivery, and motion. These lessons will culminate in a complete design project, for which students will use rapid fabrication equipment to make a prototype that moves.

Prerequisites: 24-104 or 24-101

Course Website: <https://www.meche.engineering.cmu.edu/>**24-213 Special Topics: Citizen Science: Sensors, Makers and the Environment**

Spring: 9 units

This course will introduce students to technical aspects of citizen science, using air pollution as a case study. Students will learn about important air pollutants and the environmental regulations that govern these pollutants in the U.S. Students will be introduced to data quality requirements for applications ranging from regulatory pollutant monitoring to education/outreach. Students will also learn about operating principles for both laboratory- and consumer-grade pollutant monitoring equipment. The class will culminate in a project where student teams will design, construct, and test a low-cost air pollutant monitoring system. The groups will then deploy these sensor packages to collect and present their data. The project will use the TechSpark maker space. It is primarily aimed at non-engineering majors.

24-214 IDeATe Special Topics: Mazes

Fall: 9 units

Labyrinths have been a part of our culture for millennia, from Greek myths to Renaissance palaces, to childrens pastime. The mental challenge of traversing a maze combines both the intuitive and the systematic processes that delight our human experience. As our society becomes more sedentary, the rebirth of the physical maze can serve as a bridge from the pure mental exercise to increased mobility, especially if they are modernized to become more dynamic, more adaptable, more portable, more modern. This course will allow students to study the history of labyrinths and to discover how to design and build fun, challenging, technically-enhanced, and community-engaging mazes.

24-215 IDeATe Special Topics: Human Sized Energy Sources

All Semesters: 9 units

Energy is the foundation of human technology. The great challenges of our civilization, poverty, health, environment, peace, clean water, etc. are all tied to our ability to safely generate and efficiently use energy. This course will introduce the students to the diverse methods of small, portable generation including Faraday devices, solar collection, micro-hydro, wind, etc. By designing and building small-scale, "human-size" generation systems, this course seeks to make the science and technology related to the generation of electricity more accessible to individuals with the goal of increasing awareness of how energy touches all aspects of our daily lives.

24-221 Thermodynamics

Fall: 10 units

Temperature and thermometry; equations of state for fluids and solids; work, heat, and the first law; internal energy, enthalpy, and specific heats; energy equations for flow; change of phase; the second law, reversibility, absolute temperature, and entropy; combined first and second laws; availability; power and refrigeration cycles. Applications to a wide range of processes and devices. 3 hrs. lec., 1 hour recitation

Prerequisites: (33-141 or 33-151 or 33-106 or 33-121) and 21-122 Min. grade C and 24-101

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-231 Fluid Mechanics**

Spring: 10 units

Hydrostatics. Control volume concepts of mass, momentum, and energy conservation. Euler's and Bernoulli's equations. Viscous flow equations. Head loss in ducts and piping systems. Dimensional analysis and similitude as an engineering tool. Measurement techniques. 3 hrs. lec., 1 hr. rec.

Prerequisites: (33-151 or 33-141 or 33-106) and 21-122 Min. grade C

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-251 Electronics for Sensing and Actuation**

Fall and Spring: 3 units

Mechanical engineers design, build, and troubleshoot basic circuits that perform signal conditioning on sensor measurements and provide power amplification for actuation. This course covers the basics of passive circuit design, applications of operational amplifiers, and the use of transistors to amplify low power signals coming from microcontrollers. Lecture materials are coupled with hands-on in-class exercises and homework assignments using the Arduino to interface with sensors and actuators.

Prerequisite: 24-101

24-261 Mechanics I: 2D Design

Fall: 10 units

This is the first course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the first semester, students review and extend methods of 2D statics to study single and multiple bodies, such as structures and machines. Internal loads in 2D are defined and quantified, followed by a study of stresses and strains under axial loading, bending and shear. Students will also learn engineering design process methods and skills, including concept design, detailed design, analysis, fabrication, and testing. As topics are introduced and applied by students in hands-on assignments, they will compare theoretical computations and experimental testing of their design ideas, so as to reinforce fundamentals and practice the engineering design process.

Prerequisites: 21-122 Min. grade C and (33-141 or 33-121 or 33-151 or 33-106) and 24-101

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-262 Mechanics II: 3D Design**

Spring: 10 units

This is the second course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. In the second semester, students extend their foundation in 2D statics to the analysis of 3D engineering systems, including determination of reactions at connections and internal loads. Friction, shear stress, and shear strain are introduced, followed by a study of stresses and deformation in torsion. Multiaxial stresses, such as those occurring in combinations of torsion and bending or in pressure vessels, are studied. Stress transformations are introduced, as well as the formulation of simple failure criteria. Students will expand their engineering design skills through team-based hands-on and computational projects that utilize stress and failure analysis of 3D engineered systems. In addition, students will learn elementary aspects of machine design and catalog selection to support projects. Altogether, students will learn to express ideas in sketches, interpret and create engineering drawings, model detailed shapes with CAD tools, analyze product performance with CAE tools, choose materials and manufacturing schemes, and create and test prototypes.

Prerequisites: (33-106 or 33-141 or 33-151) and 24-261

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-280 Special Topics: C++ Programming for Engineers**

Fall and Spring: 9 units

Using the C++ programming language as a platform, this course serves as an intermediate-level programming course with a strong emphasis on software requirements for engineering applications. Students will refine and enhance their coding skills while applying their mathematical, analytical and design backgrounds. Topics covered include data structures, algorithm design, numerical computation, modular programming, data modeling, interactive graphics, object-orientation, and user interfaces, all in an engineering-specific domain.

Prerequisites: 15-112 or 15-110

Course Website: <http://www.cmu.edu/me> (<http://www.cmu.edu/me/>)**24-281 Introduction to Scientific Computing**

Fall and Spring: 2 units

This course provides an introduction to scientific computing with Matlab for engineers. The course introduces the basics of Matlab syntax and programming, data analysis, visualization, curve fitting and interpolation, symbolic computation, differential equations, and debugging. The use of Matlab in solving mechanical engineering applications will be demonstrated.

Course Website: <https://www.meche.engineering.cmu.edu/>

24-291 Environmental Systems on a Changing Planet

Fall: 9 units

This course introduces the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. Environmental systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. The course will explore how solar and biochemical energy moves through the Earth's interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with environmental systems. Case studies include the interplay between climate change feedbacks, wildfires, and forest ecosystems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the environmental, scientific, and information literacy required to understand current environmental issues that are frequently debated in the public sphere. This course draws on principles learned in high school science and satisfies the science requirement for the interdisciplinary Minor in Environmental and Sustainability Studies.

24-292 Renewable Energy Engineering

Intermittent: 9 units

Introduction to engineering principles of various renewable energy systems, including the following topics: background on climate change and carbon sequestration, engineering analysis of renewable energy systems such as solar photovoltaic, (solar thermal), wind power, hydropower, wave energy, bio mass energy, geothermal energy, and hydrogen based fuel cells. In addition, transitional energy systems such as nuclear power and advanced combined cycles will be introduced. Both engineering performance and present state of development will be discussed. Students will review and present their progress on various subjects, which will be selected based on personal interest.

Prerequisites: 33-106 or 33-141

Course Website: <http://www.andrew.cmu.edu/user/satbirs/24292/>**24-300 Maker Series: Intro to CNC Machining**

Fall and Spring: 2 units

This course teaches safe operation of CNC machining equipment through structured hands-on activities. A significant portion of the course is dedicated to learning CAM software for fabrication of 2D and 3D parts. The skills learned in this course can be applied to fabricate durable components for design projects, research equipment, and extracurricular activities. 2-unit mini (7-weeks)

Prerequisite: 24-200

24-302 Professional Development for Mechanical Engineers

Fall and Spring: 2 units

This course prepares students to communicate verbally as an engineer. Students will practice and receive feedback on their oral communication in a range of contexts, including formal presentations, elevator pitches, job interview questions, and communicating technical concepts to non-engineers. In addition, students will be introduced to a range of professional topics, including ethical decision-making, communicating in global contexts, negotiation strategies, and strategies for overcoming implicit bias. Student grades will be based upon weekly homework assignments, formal presentations, and class participation.

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-311 Numerical Methods**

Spring: 12 units

Use of numerical methods for solving engineering problems with the aid of a digital computer. The course will contain numerical methods such as roots of equations, linear algebraic equations, optimization, curve fitting, integration, and differential equation solving. MATLAB will be used as the programming language. Programming cluster laboratory times will be available twice a week. Problems will be drawn from all fields of interest to mechanical engineers. 3 hrs. lecture plus lab

Prerequisite: 21-260

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-321 Thermal-Fluids Experimentation**

Spring: 12 units

Thermal-Fluids Experimentation Spring: 12 units This is a capstone course for the thermal-fluids core-course sequence. This course covers techniques of measurement, uncertainty analysis, and realization of systems, which demonstrate fundamental principles in thermodynamics, fluid mechanics, and heat transfer. The principles of designing thermal experiments are also integrated into this course.

Prerequisites: 24-231 and 24-322 and 24-221

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-322 Heat Transfer**

Fall: 10 units

Introduction to basic concepts of engineering heat transfer. Steady and transient heat conduction in solids, including the effect of heat generation. Finned surfaces. Correlation formulas for forced and free convection, condensation, and boiling. Design and analysis of heat exchangers. Radiation heat transfer. Problems in combined convection and radiation. Measurement techniques. 3 hrs. lec., 1 hr. recitation.

Prerequisites: 21-260 Min. grade C and 24-231 and 24-221

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-334 Introduction to Biomechanics**

Fall: 9 units

This course covers the application of solid and fluid mechanics to living tissues. This includes the mechanical properties and behavior of individual cells, the heart, blood vessels, the lungs, bone, muscle and connective tissues as well as methods for the analysis of human motion.

Prerequisite: 24-231

Course Website: <http://www.cmu.edu/me/>**24-341 Manufacturing Sciences**

Spring: 9 units

This course has two broad concerns: an introductory review of manufacturing systems organization and a review of common manufacturing processes from the point of view of design for manufacturability. The features of mass and batch production are quantitatively considered. The basic principles of group technology and production planning are outlined. The use of computers in manufacturing is described, together with a review of the current capabilities of industrial robots. Students will be involved in weekly seminars, which will describe the basic features of common manufacturing processes, including metal machining, metal forming, polymer processing, casting techniques, joining techniques, ceramic processing, and powder processing. Case studies from industry and films may be used. 3 hrs. rec.

Prerequisite: 24-262

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-351 Dynamics**

Fall: 10 units

This first course on the modeling and analysis of dynamic systems concentrates on the motion of particles, systems of particles, and rigid bodies under the action of forces and moments. Topics include the kinematics of motion in rectangular, polar, and intrinsic coordinates; relative motion analysis with multiple reference frames; and planar kinetics through the second law, work-energy method, and impulse-momentum method. Time and frequency domain solutions to first and second order equations of motion are discussed. 3 hrs. lec. 1 hr rec.

Prerequisites: 24-101 and 21-260 Min. grade C

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-352 Dynamic Systems and Controls**

Fall and Spring: 12 units

This second course on the modeling and analysis of dynamic systems emphasizes the common features, which are exhibited by physical systems that include mechanical, hydraulic, pneumatic, thermal, electrical, and electromechanical elements. State equations and the concepts of equilibrium, linearization, and stability are discussed. Time and frequency domain solutions are developed. 4 hr. lec.

Prerequisites: (21-260 Min. grade C and 24-251 and 33-107) or (24-251 and 21-260 Min. grade C and 33-142) or (33-152 and 21-260 Min. grade C and 24-251) or (21-260 Min. grade C and 33-132 and 24-251)

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-354 Mechatronics Applications in Mechanical Engineering

Fall: 9 units

Most modern products contain elements of sensing, actuation, and control. This course builds on concepts from Dynamic Systems and Control to design simple mechatronic systems. Topics include modeling and selection of sensors and actuators, measurement systems, digital signal processing, microcontroller architectures, and the basics of state space control methods; these topics are taught in the context of integration with mechanical systems. This course includes a substantial project component in which students design, build, and test a mechatronic system through a series of subsystem prototypes and systems integration.

Prerequisite: 24-352

Course Website: <http://www.cmu.edu/me/>**24-358 Culinary Mechanics**

Intermittent: 9 units

This course discusses how mechanical quantities and processes such as force, motion, and deformation influence food and the culinary arts. The aim of the course is to apply important aspects of mechanics to ideas in cooking. Specific topics include: (1) how do stress and strain affect food and its perceived taste; (2) what is the role of cell mechanics in the resulting micro structure of both consumed plant and animal tissues; (3) how can mechanics be used to alter nutrition; (4) what are the roles of common and uncommon mechanical tools such as a knife or mortar and pestle in food preparation. Emphasis will be placed on the biomechanics of edible matter across multiple length scales, including at the tissue, cellular, and molecular levels; additionally, impact on global health and engineering implications will be elucidated. During this course, we will introduce you to these concepts, train you to use them in real world applications, and allow you to pursue a creative group-defined project, which will be shared in both written and oral formats. We will integrate a hands-on kitchen experience in at least 3 specific laboratory classes so that students will get a true feel and understanding for culinary mechanics. We also will be visiting the restaurant of at least one first-rate Pittsburgh chef to gain real world insight into mechanics and cooking.

Course Website: <http://www.cmu.edu/me/>**24-370 Mechanical Design: Methods and Applications**

Fall: 12 units

This is the third course in a three-semester sequence that integrates the principles of mechanics with hands-on projects that have students apply those principles in a design context. Building on the principles and design methodology introduced in the first two courses, this course consists of a detailed study of typical loading conditions and resulting stresses and deflections in commonly used machine elements, such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, and bearings, and best practices in their design and application. Machine design against static and dynamic failure will be considered with focus on the effect of material properties, manufacturability, and cost considerations. Students will also learn the connections between theory and analytical methods, available computational tools, and field design. Learning objectives will be assessed through homework, class exams, and the conduct of the group projects.

Prerequisites: 24-262 and 24-200

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)**24-371 Special Topics: Design of Machine Elements**

Spring: 9 units

In this class, the students will gain an understanding of the best practices in the design of machine elements such as shafts, gears, power screws, fasteners, brakes/couplings, flywheels, bearings, etc. The course material consists of the study of stress and deflection under common loading conditions, effect of material properties, static and fatigue failure models, cost considerations, and manufacturability in the context of the machine components. Student learning will be achieved through interactive lectures on underlying technical approaches in conjunction with a group project where students will be required to design and fabricate an ensemble of machine elements. Students will also learn about the strong connections between theory, analytical methods, available computational tools, and field design. Assessment of the learning objectives will happen via homework, class exams, and demonstration of the group project. This course builds upon the skills and methods taught in Design-I (24-370) and will help students prepare to enter the modern workplace where mechanical design takes place.

Prerequisite: 24-370

24-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum

Fall: 3 units

This 3-unit course is an add-on to the co-requisite course 24-291, Environmental Systems on a Changing Planet. While 24-291 is designed to be accessible to students from all Colleges and major, this add-on course 24-381 allows students to engage with the material with more technical depth and quantitative understanding. 24-381 is intended for students from STEM majors in the colleges of Computer Science, Engineering, and Science, but can be taken by any student that is interested in exploring the environmental science topics with greater depth. Science and engineering fundamentals will be further developed and applied to deepen the quantitative understanding of the function and feedbacks of complex environmental systems. 24-381 along with 24-291 introduce the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. Please refer to the course description for 24-291 for more information. This course draws on principles learned in introductory science and engineering courses at CMU and serves as the foundational Earth and amp; Environmental Science requirement for both the interdisciplinary Minor and Additional Major in Environmental and Sustainability Studies. 24-381 highly recommended for students enrolled in the College of Engineering, Mellon College of Science, and School of Computer Science. When taken with 24-291, 24-381 will count as a technical elective for most programs in these STEM colleges, while 24-291 on its own is not considered a technical elective for STEM programs.

24-390 Mechanical Engineering Co-op

Fall and Spring

The Department of Mechanical Engineering at Carnegie Mellon considers practical learning opportunities important educational options for its undergraduate students. One such option is cooperative education, which provides a student with an extended work experience with a company or government institution. To participate, students must possess at least junior status and have an overall grade point average of 3.0 or above. Students must complete a Co-Op Approval Form and submit it for approval. If the application is approved, the course will be added to the student's schedule and the student will be assessed tuition for 0 units for each semester that the student participates. All co-ops must be approximately 5-8 months in uninterrupted length. Upon completion of the co-op experience, students must submit a 1-2 page report of their work experience, and a 1-2 page evaluation from the company supervisor to the ME Undergraduate Education Committee. If the reports are approved, a "P" grade will be assigned. International students should contact their academic advisor for additional information. Prerequisite: Special permission required

Course Website: <https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html> (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/>)**24-391 Mechanical Engineering Project**

Fall and Spring

Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: <https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html> (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/>)**24-392 Mechanical Engineering Project**

All Semesters

Practice in the organization, planning, and execution of appropriate engineering projects. These investigations may be assigned on an individual or a team basis and in most cases will involve experimental work.

Course Website: <https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html> (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/>)**24-421 Internal Combustion Engines**

Fall: 12 units

This course discusses working principles of internal combustion engines found in many practical applications. Focus is given to understanding the design of air handling system, in-cylinder fuel/air mixing, geometric design of the combustion chamber, engine performance and calibration, and mechanism of pollutant formation and reduction. Introductory discussion of advanced automotive engine concepts, alternative fuels, gas turbine engines, rocket engines, and hybrid electric vehicles is also provided. The course relies on a number of lab experiments, analysis of actual experimental data, and a combination of analytical and numerical homework assignments. 3 hrs. lecture 2 hrs. lab

Prerequisites: 24-221 and 24-231

Course Website: <http://www.andrew.cmu.edu/user/satbirs/24421/>

24-424 Energy and the Environment

Fall: 9 units

Fuel cycles for conventional and non-conventional energy resources; relationships between environmental impacts and the conversion or utilization of energy; measures of system and process efficiency; detailed study and analysis of coal-based energy systems including conventional and advanced power generation, synthetic fuels production, and industrial processes; technological options for multi-media (air, water, land) pollution control; mathematical modeling of energy-environmental interactions and tradeoffs and their dependency on technical and policy parameters; methodologies for energy and environmental forecasting; applications to issues of current interest. Junior or Senior standing in CIT or permission of instructor. 3 hrs lecture

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-425 Combustion and Air Pollution Control

Intermittent: 9 units

Formation and control of gaseous and particulate air pollutants in combustion systems. Basic principles of combustion, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, and flame structure. Formation of gaseous and particulate pollutants in combustion systems. Combustion modifications and post-combustion technologies for pollutant control. Relationship between technology and regional, national, and global air pollution control strategies. The internal combustion engine and coal-fired utility boiler are used as examples. 3 hours lecture Cross listed as 24-740 and 19440/19-740

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-428 Computational Analysis of Transport Phenomena

Spring: 9 units

In this course, students will develop basic understanding and skill sets to perform simulations of transport phenomena (mass, momentum, and energy transport) for engineering applications using a CAE tool, learn to analyze and compare simulation results with theory or available data, and develop ability to relate numerical predictions to behavior of governing equations and the underlying physical system. First 8 weeks of the course will include lectures and simulation-based homework assignments. During last 7 weeks, teams of students will work on self-proposed projects related to computational analysis of transport phenomena. In the project, students will learn to approach loosely defined problems through design of adequate computational mesh, choice of appropriate numerical scheme and boundary conditions, selection of suitable physical models, efficient utilization of available computational resources etc. Each team will communicate results of their project through multiple oral presentations and a final written report. Detailed syllabus of the course is provided on the URL given below. Prerequisites: 24-231 and 24-322 and 24-221

Course Website: <http://www.andrew.cmu.edu/user/satbirs/24618/>

24-441 Product Design

Fall and Spring: 12 units

This course guides students through the design process in the applied design of a practical mechanical system. Lectures describe the typical design process and its associated activities, emphasizing methods for innovation and tools for design analysis. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is typically completed in teams and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation. Frequently, a working model will also be required. Oral progress reports and a final written and oral report are required. 3 hrs. rec., 3 hrs lab Senior standing and Machine Shop Practice 24-200 required. Prerequisite: 24-370

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-451 Feedback Control Systems

Fall: 12 units

Fundamentals of feedback control with emphasis on classical techniques and an introduction to discrete-time (computer controlled) systems. Topics include the following: frequency domain modeling and state space modeling of dynamical systems; feedback control system concepts and components; control system performance specifications such as stability, transient response, and steady state error; analytical and graphical methods for analysis and design - root locus, Bode plot, Nyquist criterion; design and implementation of proportional, proportional-derivative, proportional-integral-derivative, lead, lag, and lead-lag controllers. Extensive use of computer aided analysis and design software. 4 hrs lec. Prerequisites: (15-112 or 15-110) and 24-352

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-452 Mechanical Systems Experimentation

Fall and Spring: 9 units

Experimentation in dynamic systems and controls. The course will cover translational and rotational systems. Topics will include mechanical elements, natural frequencies, mode shapes, free and forced response, frequency response and Bode plots, time constants, transient response specifications, feedback controls such as PID control, and stability for single-degree-of-freedom and multi-degree-of-freedom systems. The course will introduce and use state-of-the-art experimentation hardware and software. Prerequisite: 24-352

Course Website: <http://www.cmu.edu/me/undergraduate/index.html> (<http://www.cmu.edu/me/undergraduate/>)

24-453 Special Topics: Introduction to Programmable Logic Controllers

Fall and Spring: 3 units

Programmable Logic Controllers (PLCs) are prevalent in many industrial process control and manufacturing applications. Knowledge of and experience with PLCs is a marketable skill, opening up many career opportunities in a wide range of industries. This course provides an introduction to the applications of PLCs and techniques used for their programming and implementation. The course will be primarily lab-based, aimed at introducing the capabilities, limitations, and applications of PLCs through hands-on experience. Topics include ladder logic, PLC programming, PLC memory structures, program execution, troubleshooting methods, and typical industrial practices. Prerequisite: 24-352

24-480 Special Topics: Artificial Intelligence and Machine Learning for Engineering

Spring: 9 units

This course introduces algorithms that are at the center of modern day artificial intelligence (AI) and machine learning (ML) techniques. The course takes an engineering-focused approach to AIML by investigating the wide array of sources of data available in the world, how these sources generate data, and algorithms and methods that are used to transform this data into knowledge/insights. Prerequisites: (15-112 or 15-110) and (19-250 or 36-225 or 36-217 or 36-220)

24-491 Department Research Honors

Fall and Spring

This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: <https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html> (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/>)

24-492 Department Research Honors

Fall and Spring

This course is designed to give students increased exposure to "open-ended" problems and research type projects. It involves doing a project on a research or design topic and writing a thesis describing that project. The project would be conducted under the supervision of a mechanical engineering faculty member (the advisor), and must be approved by the advisor before inception. This course can be taken at any time after the Junior year and before graduation which includes the summer after the Junior year. Completion of 18 units of this course with a grade of B or better is a partial fulfillment of the requirements for Departmental Research Honors.

Course Website: <https://www.meche.engineering.cmu.edu/education/undergraduate-education/index.html> (<https://www.meche.engineering.cmu.edu/education/undergraduate-education/>)

24-602 Maker Series: Prototyping for Equity

Spring

This course applies prototyping techniques to develop products for underserved populations of people. In order to fabricate components for prototypes, this course teaches the safe operation of fabrication tools, including 3D printer, laser cutter-engraver machine, and power tools. A significant portion of the course is dedicated to applying the engineering design cycle to meet the unique needs/wants of a specific user population. This hands-on course culminates in building a prototype that can be tested to validate its performance as the physical solution to a real-world problem. 5-6-unit mini (7-weeks)

24-614 Microelectromechanical Systems

Intermittent: 12 units

This course introduces fabrication and design fundamentals for Microelectromechanical Systems (MEMS): on-chip sensor and actuator systems having micron-scale dimensions. Basic principles covered include microstructure fabrication, mechanics of silicon and thin-film materials, electrostatic force, capacitive motion detection, fluidic damping, piezoelectricity, piezoresistivity, and thermal micromechanics. Applications covered include pressure sensors, micromirror displays, accelerometers, and gas microsensors. Grades are based on exams and homework assignments.

Prerequisites: 18-321 or 24-351

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-623 Molecular Simulation of Materials

Spring: 12 units

The purpose of this course is to expose engineering students to the theory and implementation of numerical techniques for modeling atomic-level behavior. The main focus is on molecular dynamics and Monte Carlo simulations. Students will write their own simulation computer codes, and learn how to perform calculations in different thermodynamic ensembles. Consideration will be given to heat transfer, mass transfer, fluid mechanics, mechanics, and materials science applications. The course assumes some knowledge of thermodynamics and computer programming. 4 hrs lec. Prerequisites: 24-311 and 24-221

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-626 Air Quality Engineering

Intermittent: 12 units

The course provides a quantitative introduction to the processes that control atmospheric pollutants and the use of mass balance models to predict pollutant concentrations. We survey major processes including emission rates, atmospheric dispersion, chemistry, and deposition. The course includes discussion of basic atmospheric science and meteorology to support understanding air pollution behavior. Concepts in this area include vertical structure of the atmosphere, atmospheric general circulation, atmospheric stability, and boundary layer turbulence. The course also discusses briefly the negative impacts of air pollution on society and the regulatory framework for controlling pollution in the United States. The principles taught are applicable to a wide variety of air pollutants but special focus is given to tropospheric ozone and particulate matter. The course is intended for graduate students as well as advanced undergraduates. It assumes a knowledge of mass balances, fluid mechanics, chemistry, and statistics typical of an undergraduate engineer but is open to students from other scientific disciplines. 12 units

Prerequisites: 09-105 and 36-220 and 24-231

Course Website: <http://www.cmu.edu/me/>

24-628 Energy Transport and Conversion at the Nanoscale

Spring: 12 units

Energy transport and conversion processes occur at the nanoscale due to interactions between molecules, electrons, phonons, and photons. Understanding these processes is critical to the design of heat transfer equipment, thermoelectric materials, electronics, light emitting diodes, and photovoltaics. The objective of this course is to describe the science that underlies these processes and to introduce the contemporary experimental and theoretical tools used to understand them. The course includes a laboratory that gives the students experience with modern transport measurement instrumentation and data analysis. Integrated literature reviews and a final project require students to apply learned fundamentals to understand state-of-the-art research and technology. 4 hrs. lecture Prerequisites- 24-322 and amp; 24-221 or equivalents Prerequisites: 24-322 and 24-221

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-629 Direct Solar and Thermal Energy Conversion

Intermittent: 12 units

This course introduces graduates and senior undergraduates the principles and technologies for directly converting heat and solar light into electricity using solid-state devices. The first part of the course reviews the fundamentals of quantum mechanics, solid state physics and semiconductor device physics for understanding solid-state energy conversion. The second part discusses the underlying principles of thermoelectric energy conversion, thermionic energy conversion, and photovoltaics. Various solar thermal technologies will be reviewed, followed by an introduction to the principles of solar thermophotovoltaics and solar thermoelectrics. Spectral control techniques which are critical for solar thermal systems will also be discussed. By applying the basic energy conversion theory and principles covered in lectures, students will finish a set of 4 homework assignments. This course also requires one project in which students will work individually to review one present solar or thermal energy conversion technology 12 units

Course Website: <http://www.cmu.edu/me/>

24-631 Thermal Design

Spring: 12 units

This course guides students through the design process of a practical thermal system. The course plan assumes a mastery of the fundamentals of thermodynamics, fluid mechanics and heat transfer at the undergraduate level. Lectures aim at design aspects and analysis techniques commonly used in the development of thermal systems. Lecture topics include heat sinks, heat pipes, compact heat exchangers, sensors and instrumentation, thermoelectric devices, and special topics closely related to the theme of the design activity for the semester. Design activity is conducted in teams and includes several cycles of oral presentations, class discussions, and a final written report. System design and analysis of performance are heavily based on computer-aided design tools and simulation means. Student performance in this course is evaluated based on individual homework assignments on the various topics presented in class and on a team design project.

Prerequisite: 24-322

24-632 Special Topics: Additive Manufacturing Processing and Product Development

Fall: 12 units

Introduction to additive manufacturing (AM) processing fundamentals and applications using Solidworks 3-D CAD software and a variety of polymer and metal AM machines. Includes a brief history of AM processing, a review of and technical fundamentals of current AM processes, a study of the current AM market, and future directions of the technology. Lab Sessions will support an open-ended product development project. Lectures on metals AM will address current research impacting industry. Students will also perform a literature review of papers on the state of the art. Basic Solidworks knowledge required.

Course Website: <http://www.cmu.edu/me/>

24-633 Additive Manufacturing Laboratory

Spring: 12 units

Hands-on laboratory projects will teach students about all aspects of metals additive manufacturing (AM). Students will learn how to use SOLIDWORKS for part design, create and transfer design files to the AM machines, run the machines to build parts, perform post-processing operations, and characterize AM parts. Students will work in teams and complete three separate lab projects, each utilizing a different material system, part design, AM process/machine, post-processing steps and characterization methods. A major lab report and presentation will be required for each of the three lab projects. The course includes weekly lectures to complement the laboratory component. Priority for enrollment will be given to students who have declared the Additive Manufacturing Minor.

Prerequisites: 27-503 or 24-632 or 39-602 or 39-601 or 27-765

24-635 Structural Analysis

Fall: 12 units

Classical and matrix-based methods of structural analysis; energy principles in structural mechanics. Basic concepts of force and displacement methods for analyzing redundant structural systems. Matrix methods utilizing the flexibility (force) and stiffness (displacement) concepts.

Prerequisite: 24-262

24-636 Energy Applications in Biology and Medicine

Spring: 12 units

This course covers a wide range of energy-based applications in biology and medicine, such as cancer treatments by cryosurgery (freezing), thermal ablation (heating), photodynamic therapy (light-activated drugs), and irreversible electroporation (a non-thermal electrical application). This course also covers thermal regulation in humans and other mammals, as well as cryopreservation (low-temperature preservation) of tissues and organs for the benefit of organ banking and transplant medicine. The course combines lectures and individual assignments relating to the underlying principles of engineering, with teamwork on open-ended projects relating to concurrent challenges at the convergence of engineering and medical sciences. The course plan assumes a mastery of the fundamentals of heat transfer at the undergraduate level

Prerequisite: 24-322

24-640 Climate Change Mitigation

Intermittent: 12 units

Have you ever thought about how we could address the climate change problem? In this course we will study the technological and policy options for responding to the threat of climate change. We will review climate-change science, understand the current systems for energy supply and use, and have a deep dive onto technological solution for low-carbon energy supply and use, as well as the policy frameworks that can help us reduce greenhouse gas emissions. 2hrs 40min of lectures per week.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-643 Energy Storage Materials and Systems**

Intermittent: 12 units

Contemporary energy needs require large scale electrochemical energy conversion and storage systems. Batteries are playing a prominent role in portable electronics and electric vehicles. This course introduces principles and mathematical models of electrochemical energy conversion and storage. Students will study thermodynamics, reaction kinetics pertaining to electrochemical reactions, phase transformations relating to batteries. This course includes applications to batteries, fuel cells, supercapacitors

Course Website: <http://www.andrew.cmu.edu/user/venkatv/24643/>**24-650 Applied Finite Element Analysis**

Intermittent: 12 units

This is an introductory course on the finite element method with emphasis on application of the method to a wide variety of problems. The theory of finite element analysis is presented and students learn various applications of the method through assignments utilizing standard finite element software packages commonly used in industry. Various types of analyses are considered, which may include, for example, static, pseudo-static, dynamic, modal, buckling, contact, heat transfer, thermal stress and thermal shock. Students also learn to use a variety of element types in the models created, such as truss, beam, spring, solid, plate, and shell elements.

Prerequisites: 24-322 and 24-262

Course Website: <https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html> (<https://www.meche.engineering.cmu.edu/education/graduate-programs/>)**24-653 Special Topics: Materials and Their Processing for Mechanical Engineers**

Spring: 12 units

The study of the major classes of materials (e.g., metals, alloys, ceramics, polymers, composites) and their structure-processing-property relationships is integral to many engineering disciplines. This course will introduce the fundamental concepts behind how the processing of materials influences their atomic/molecular structures and resulting properties. The course will adopt a game-based learning approach in which students will utilize the virtual Minecraft environment to study crystal structures, imperfections (defects), diffusion, and phase equilibria. These concepts are then applied to characterize and interpret the (mechanical, electrical, magnetic, and optical) properties of various material systems as part of a final collaborative group project.

24-654 Special Topics: Welding Engineering

Spring: 12 units

This course introduces the Welding Engineering field by teaching its fundamental aspects (e.g. metallurgy, solidification, heat transfer, arc physics, etc.) as applied to welding common ferrous and non ferrous materials with representative fusion (e.g. GMAW, LBW) and solid-state (e.g. FSW, FW) based processes and aspects of their use in production (i.e. variables to control, specific techniques and methodologies, standards/specifications, inspection and amp; testing of welds to ensure their quality). This will provide students with the knowledge to start to become more conversant in this discipline and to those that elect to further delve and specialize in specific areas of joining and amp; assembly, the preparation/step-stone to start to do so in their careers in industry or academia.

24-655 Cellular Biomechanics

Intermittent: 9 units

This course discusses how mechanical quantities and processes such as force, motion, and deformation influence cell behavior and function, with a focus on the connection between mechanics and biochemistry. Specific topics include: (1) the role of stresses in the cytoskeleton dynamics as related to cell growth, spreading, motility, and adhesion; (2) the generation of force and motion by moot molecules; (3) stretch-activated ion channels; (4) protein and DNA deformation; (5) mechanochemical coupling in signal transduction. If time permits, we will also cover protein trafficking and secretion and the effects of mechanical forces on gene expression. Emphasis is placed on the biomechanics issues at the cellular and molecular levels; their clinical and engineering implications are elucidated. 3 hrs. lec. Prerequisite: Instructor permission.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-658 Image-Based Computational Modeling and Analysis**

Spring: 12 units

Image-based computational modeling and analysis play an important role in mathematical modeling and computer simulation of many physical and biological phenomena. This course integrates mechanical engineering, biomedical engineering, material sciences, computer science, and mathematics together. Topics to be studied include scanning techniques, image processing, geometric modeling, mesh generation, computational mechanics, as well as broad applications in biomedicine, material sciences and engineering. The techniques introduced are applied to examples of multi-scale modeling and simulations in various research fields.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-663 Special Topics: Biomechanics of Human Movement**

Spring: 12 units

This course provides an overview of the mechanical principles underlying human movement biomechanics and the experimental and modeling techniques used to study it. Specific topics will include locomotion, motion capture systems, force plates, muscle mechanics, musculoskeletal modeling, three dimensional kinematics, inverse dynamics, forward dynamic simulations, and imaging-based biomechanics. Homework and final class projects will emphasize applications of movement biomechanics in orthopedics, rehabilitation, and sports. ***Students are expected to have knowledge of ordinary differential equations and rigid body dynamics at the level of 24-351.***

24-664 Introduction to Biomechanics

Fall: 12 units

The purpose of this course is to achieve a broad overview of the application of mechanics to the human body. This includes solid, fluid, and viscoelastic mechanics applied to single cells, the cardiovascular system, lungs, muscles, bones, and human movement. The physiology of each system will be reviewed as background prior to discussing mechanics applications within that system. There are no firm prerequisites, but statics, fluid mechanics, and biology are helpful.

Course Website: <http://www.cmu.edu/me/>**24-665 Special Topics: Wearable Health Technologies**

Spring: 12 units

This project-based course will provide an overview of emerging wearable health technologies and give students hands-on experience in solving ongoing technical challenges. The wearable sensing field is experiencing explosive growth, with exciting applications in medicine. New lightweight devices will make it easier to monitor health conditions in real time, automatically import data into health informatics systems, and provide haptic feedback with humans in the loop. We will review several aspects of these technologies, including hardware, software and big data analytics, user experience, and applications. Students will be working collaboratively in a semester-long project that tackles timely experimental and computational challenges. Programming experience, in any language, is a pre-requisite.

Course Website: <https://www.meche.engineering.cmu.edu/education/courses/24-665.html>**24-666 Special Topics: Introduction to Geometric Dimensioning and Tolerancing**

Spring: 3 units

Geometric Dimensioning and Tolerancing (GD and μ T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and μ T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.

Prerequisite: 24-370

24-667 Special Topics: Introduction to Geometric Dimensioning and Tolerancing

Spring: 6 units

Geometric Dimensioning and Tolerancing (GD and μ T) encompasses a language and system of rules used to precisely and unambiguously communicate the intended geometry and allowable variation of manufactured objects. This tolerance informs the design, process selection, tooling, and inspection of a part. This course will introduce students to this system of communication and its applications. Topics will include interpreting GD and μ T on engineering drawings, implementing it in Solidworks, and performing tolerance analyses.

24-671 Electromechanical Systems Design

Fall: 12 units

This course guides students through the design process as applied to mechatronic systems, which feature electrical, mechanical, and computational components. Lectures describe the typical design process and its associated activities, emphasizing methods for analyzing and prototyping mechatronic systems. Professional and ethical responsibilities of designers, interactions with clients and other professionals, regulatory aspects, and public responsibility are discussed. The design project is team-based and is based on a level of engineering knowledge expected of seniors. Proof of practicality is required in the form of descriptive documentation and a working prototype system at the end of the course. Oral progress reports and a final written and oral report are required. Prerequisites: 24-370 and 24-352

Course Website: <http://www.cmu.edu/me/>**24-672 Special Topics in DIY Design and Fabrication**

Fall: 12 units

The traditional principles of mass production are being challenged by concepts of highly customized and personalized goods. A growing number of do-it-yourself (DIY) inventors, designers, makers, and entrepreneurs is accelerating this trend. This class offers students hands-on experience in DIY product design and fabrication processes. Over the course of the semester, students work individually or in small groups to design customized and personalized products of their own and build them using various DIY fabrication methods, including 3D laser scanning, 3D printing, laser cutting, molding, vacuum forming, etc. In addition to design and fabrication skills, the course teaches students skills for communicating their ideas effectively through industrial design sketches and presenting their products with aesthetically refined graphics.

Course Website: <https://www.andrew.cmu.edu/course/24-672/>**24-677 Modern Control Theory**

Fall: 12 units

This course offers a practical introduction to the analysis and design of model-based control for linear systems. Topics include modeling and linearization of multi-input multi-output dynamic systems using the state-variable description, fundamentals of linear algebra (linear space, linear transformation, linear dynamics), analytical and numerical solutions of systems of linear time-invariant differential and difference equations, structural properties of linear dynamic physical systems (controllability, observability and stability), canonical realizations, and design of state feedforward/feedback, optimal, and stochastic controllers and observers (pole placement, LQR, MPC, Kalman filter approaches). Students will learn how to design linear controllers and implement them to solve real-world problems in control and robotics.

Course Website: <https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html> (<https://www.meche.engineering.cmu.edu/education/graduate-programs/>)**24-680 Quantitative Entrepreneurship: Analysis for New Technology Commercialization**

Intermittent: 12 units

This course provides engineers with a multidisciplinary mathematical foundation for integrated modeling of engineering design and enterprise planning decisions in an uncertain, competitive market. Topics include economics in product design, manufacturing and operations modeling and accounting, consumer choice modeling, survey design, conjoint analysis, decision-tree analysis, optimization, model integration and interpretation, and professional communication skills. Students will apply theory and methods to a team project for a new product or emerging technology, developing a business plan to defend technical and economic competitiveness. This course assumes fluency with basic calculus, linear algebra, and probability theory.

24-681 Computer-Aided Design

Intermittent: 12 units

This course is the first section of the two-semester sequence on computational engineering. Students will learn how computation and information technologies are rapidly changing the way engineering design is practiced in industry. The course covers the theories and applications of the measurement, representation, modeling, and simulation of three-dimensional geometric data used in the engineering designed process. Students taking this course are assumed to have knowledge of the first course in computer programming. 4 hrs lecture, 2 hrs computer cluster

Course Website: <http://www.andrew.cmu.edu/course/24-681/>**24-683 Design for Manufacture and the Environment**

Fall: 12 units

Design for Manufacturing and the Environment examines influences of manufacturing and other traditionally downstream issues on the overall design process. Manufacturing is one facet that will be examined. Other downstream influences that will be studied include: assembly, robustness and quality, platform design, maintenance and safety, economics and costing, lean manufacturing and globalization. In addition, a core part of the course will focus on environment-based design issues. The class will study basic fundamentals in each of these areas and how they affect design decisions. Prerequisites: Senior standing in mechanical engineering, or permission of instructor

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-684 Special Topics: Nanoscale Manufacturing Using Structural DNA Nanotechnology

Fall: 12 units

This course provides an introduction to modern nanoscale manufacturing using structural DNA nanotechnology. This DNA-based approach to manufacturing has much in common with other fabrication methods in micro- and nano-engineering: computer aided design tools are necessary for device design and resulting structures can only be seen using advanced microscopy. However, instead of machining larger materials down to micro- and nanostructures, DNA origami is fabricated using a "bottom up" approach for self-assembling individual oligonucleotides into 2D and 3D nanostructures. Resulting structures can be designed to have novel mechanical and electrical properties and have applications as broad-ranging as medicine, biological computing, and energy systems. The course will include lectures, hands-on physical modeling, homework problems, 3D modeling of DNA origami using caDNA and CANDO software, and student team projects and presentations.

Course Website: <https://www.mech.eengineering.cmu.edu/>**24-685 Engineering Optimization without Project**

Fall: 9 units

This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. This course is identical to 24-785 Engineering Optimization, except students in 24-685 will not complete the project, but will be responsible for any homework assignments and exams. 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project
Prerequisites: 21-259 and 21-341

Course Website: <http://www.cmu.edu/me/>**24-686 Advanced Mechanical Design**

Intermittent: 12 units

This course will build expert foundational knowledge in mechanical design. Students will perform a series of multi-week modules in which they design, fabricate, and test high-performance mechanical components or assemblies individually or in small teams. Interactive lectures and topic readings on underlying technical approaches will occur simultaneously, thereby drawing a strong connection between theory, analytical methods, computational tools, and experience-based intuition. Modules will address optimal structures for tensile, bending, buckling, and torsion conditions, fatigue life, mechanism design, fluid power system design, and optimization of dynamical system properties. This course builds on the skills and methods taught in 24-370, Engineering Design I, and students are recommended to first take 24-370 and its prerequisites or similar courses at their undergraduate institution. Priority will be given to students who have already passed 24-200 Machine Shop Practice.
Prerequisite: 24-370

Course Website: <http://www.cmu.edu/me> (<http://www.cmu.edu/me/>)**24-688 Introduction to CAD and CAE Tools**

Fall: 12 units

This course offers the hands-on training on how to apply modern CAD and CAE software tools to engineering design, analysis and manufacturing. In the first section, students will learn through 7 hands-on projects how to model complex free-form 3D objects using commercial CAD tools. In the second section, students will learn through 7 hands-on projects how to simulate complex multi-physics phenomena using commercial CAE tools.
Units: 12 Format: 2 hrs. Lec., 2 hrs. computer lab
Prerequisites: 24-231 and 24-262

Course Website: <http://www.cmu.edu/me/>**24-691 Mechanical Engineering Project Management**

Fall and Spring: 12 units

Organizations are increasingly adopting formal project management techniques to successfully initiate, plan, execute, monitor, control, and close out projects. In this course, students will learn project management tools which are commonly applied in industry. Working in teams, students will incorporate these tools into a documented plan for a project on which they are currently working or have previously completed. The project plan will address the ten knowledge areas of project management, including the management of project integration, scope, schedule, cost, quality, resources, communications, risk, procurement, and stakeholders. Students will also work in teams to plan and manage simulated projects. Real world constraints, challenges, and incentives will be applied. Additional special topics in project management will be discussed based on student interest, which may include lean, iterative, incremental, and industry-specific approaches, as well as productivity and human relations principles, and project management professional certification.

Course Website: <http://www.cmu.edu/me/>**24-693 Special Topics: Leadership and Communication**

Fall and Spring: 12 units

The objective of this course is to prepare students to be better leaders and communicators in their future careers, in industry, academia, and elsewhere. Topics include: psychological analysis of leaders and followers, negotiation and conflict resolution, interviewing, organizational decision making, and harnessing and deploying skills in challenging situations. To address these topics, the course employs new teaching techniques involving hands on activities, for example mock interviews and role playing around challenging situations. Learning outcomes include: improved ability to adapt, communicate, and lead in difficult situations in real time, understand team interactions and group dynamics to become a successful leader and follower, best practices in negotiating and resolving conflict in team situations and business interactions, and understand fundamentals of the interview process to achieve best outcomes.

24-695 Academic and Professional Development for Mechanical Engineering Masters Student

Fall: 1 unit

This course, required for all first-year masters students in the Department of Mechanical Engineering, will cover fundamental and practical topics for their academic and professional development. The course offers ten one-hour workshop sessions throughout the fall semester. A short assignment will be given after each session. The sessions will cover three categories of topics: (1) career planning, (2) graduate study, and (3) social issues. The first category covers alumni panels, Ph.D. panels, and employer information. The second category covers time management and group dynamics. The third category covers diversity, equity and inclusion, ethics, and academic integrity. Assessment Structure: Attendance and assignments

24-696 Professional Communication in Engineering

Fall and Spring: 5 units

This course, required for all masters students in the Department of Mechanical Engineering, will help students hone their written and oral communication skills for the workplace. Students will meet weekly throughout a semester to learn communication strategies, practice those strategies in formal and informal contexts, and give and receive peer feedback. There will be weekly deliverables (both written and oral) that will receive formal feedback from communication TAs. To maximize learning benefits, students will have the option to revise assignments in order to improve their skills. Topics covered include: preparing brief (30-60 second) pitches, responding to job interview questions, writing challenging emails, writing progress reports, writing executive summaries, presenting technical work to non-experts, writing project descriptions for non-experts, creating a web portfolio.

24-703 Numerical Methods in Engineering

Fall: 12 units

This course emphasizes numerical methods to solve differential equations that are important in engineering. Procedures will be presented for solving systems of ordinary differential equations and boundary value problems in partial differential equations. Students will be required to develop computer algorithms and employ them in a variety of engineering applications. Comparison with analytical results from 24-701 will be made whenever possible. 4 hrs. lec. Prerequisite: some programming experience is required.

Course Website: <http://www.cmu.edu/me/graduate/courses.html>

24-704 Probability and Estimation Methods for Engineering Systems

Fall: 12 units

Overview of rules of probability, random variables, probability distribution functions, and random processes. Techniques for estimating the parameters of probability models and related statistical inference. Application to the analysis and design of engineered systems under conditions of variability and uncertainty. 12 units Prerequisites(s) 26-211, or 36-220 or equivalent.

Cross listed CEE 12-704

Prerequisite: 36-220

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-711 Fluid Dynamics**

Fall: 12 units

This course focuses on development and application of control volume forms of mass, momentum and energy conservation laws, differential forms of these laws in Eulerian and Lagrangian coordinates, and Navier-Stokes equations. Students also explore applications to problems in incompressible and compressible laminar flows, boundary layers, hydrodynamic lubrication, transient and periodic flows, thermal boundary layers, convective heat transfer, and aerodynamic heating. 4 hrs. lec. Prerequisites: 24-701 or permission of the instructor.

Prerequisite: 24-701

Course Website: <https://www.meche.engineering.cmu.edu/>**24-718 Computational Fluid Dynamics**

Fall: 12 units

This course focuses on numerical techniques for solving partial differential equations including the full incompressible Navier-Stokes equations. Several spatial-temporal discretization methods will be taught, namely the finite difference method, finite volume method and briefly, the finite element method. Explicit and implicit approaches, in addition to methods to solve linear equations are employed to study fluid flows. A review of various finite difference methods which will be used to analyze elliptic, hyperbolic, and parabolic partial differential equations and the concepts of stability, consistency and convergence are presented at the beginning of the course to familiarize the students with general numerical methods. Detailed syllabus of the course is provided on the URL given below. 4 hr. lec Prerequisites: 24-231 and 24-311

Course Website: <http://www.andrew.cmu.edu/user/satbirs/24718/>**24-721 Advanced Thermodynamics**

Intermittent: 12 units

The course covers advanced macroscopic thermodynamics and introduces statistical thermodynamics. Review of first and second laws. Axiomatic formulation of macroscopic equilibrium thermodynamics and property relationships. Criteria for thermodynamic equilibrium with application to multiphase and multi-component systems. Thermodynamic stability of multiphase systems. Elementary kinetic theory of gases and evaluation of transport properties. Statistical-mechanical evaluation of thermodynamic properties of gases, liquids, and solids. Students are expected to have an undergraduate level of understanding of Thermodynamics (comparable to 24-221). 4 hrs. lec.

Prerequisite: 24-221

Course Website: <http://www.andrew.cmu.edu/user/venkatv/24721/>**24-722 Energy System Modeling**

Fall: 12 units

This course focuses on the thermodynamic modeling of energy systems with emphasis on energy/availability analysis techniques. These techniques are developed and applied to both established and emerging energy technologies, such as internal combustion engines, gas- and coal-fired power plants, solar and wind energy systems, thermochemical hydrogen production cycles, and fuel cells. The course will also consider the integration of components such as reformers and electrolyzers. Modern computational tools are used throughout the course. The course culminates with a group project that requires developing sophisticated, quantitative models of an integrated energy system. Students are expected to have completed an undergraduate course in thermodynamics comparable to 24-221.

Prerequisites: 24-221 or 06-221 or 27-215

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-727 Special Topics: Aerosol Measurement Technology**

Intermittent: 12 units

This course explores modern methods and instrumentation used to characterize key physical and chemical properties of aerosol particles, and the fundamental principles underlying the technology. Topics include particle sampling and collection (aerosol inlets, impactors, cyclones, virtual impactors, collection on substrates, electrostatic precipitation), aerosol charging and neutralization, particle size measurements (electrical mobility, optically, and aerodynamically based), particle detection (optical and electrical), aerosol optical properties, and the characterization of particle chemical composition (online mass spectrometry, in particular). Methods for analyzing both individual and ensembles of aerosol particles are discussed and compared. Recent advances reported in the literature are explored through student-led presentations. Students write a term paper describing and justifying their choice of techniques to solve a realistic aerosol measurement need. While the focus is on atmospheric aerosol particles, industrial applications such as particle synthesis and characterization are also discussed.

Course Website: <http://www.cmu.edu/me/>**24-730 Advanced Heat Transfer**

Spring: 12 units

This course is open to students from all areas of engineering, although an undergraduate background in heat transfer is assumed. This class is an appropriate preparation for the doctoral qualifying exam. Topics to be covered include: mathematical formulation of heat transfer problems, heat conduction, thermal radiation, hydraulic boundary layers, and laminar and turbulent convection. Problems and examples will include theory and applications drawn from a spectrum of engineering design problems. Prerequisite: Undergraduate Heat Transfer 24-322 or equivalent.

Prerequisite: 24-322

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-740 Combustion and Air Pollution Control**

Intermittent: 12 units

24-740 Combustion and Air Pollution Control This course examines the generation and control of air pollution from combustion systems. The course's first part provides a brief treatment of combustion fundamentals, including thermochemical equilibrium, flame temperature, chemical kinetics, hydrocarbon chemistry, mass transfer, and flame structure. This foundation forms the basis for exploring the formation of gaseous (oxides of nitrogen, carbon monoxide, hydrocarbons, and sulfur dioxide) and particulate pollutants in combustion systems. The course then describes combustion modifications for pollutant control and theories for pollutant removal from effluent streams. The internal combustion engine and utility boilers serve as prototypical combustion systems for discussion. The course also addresses the relationship between technology and the formulation of rational regional, national, and global air pollution control strategies. Cross listed 19-740, 19-440, 24-425

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-751 Introduction to Solid Mechanics I**

Fall: 12 units

This is the first course in a two-part professionally oriented course sequence covering a variety of important problems in solid mechanics. Topics covered typically include torsion of non-circular cross sections, the field equations of elasticity and boundary conditions, and a number of classical plane stress/ plane strain solutions in rectangular and polar coordinates. Emphasis is placed on not only elasticity theory and how classical elasticity solutions are derived, but also on their use in constructing and interpreting the results from finite element simulations of applied engineering problems. Where applicable, comparisons are also made between solutions derived via the full theory of elasticity and simplified solutions developed in strength of materials courses. 4 hrs. lec.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-753 Special Topics: Robotic Materials: Designs, Principles & Mechanics

Fall and Spring: 12 units

This is an interdisciplinary course focused on principles, theoretical models, and material architectures relevant to applications of condensed soft matter to problems in engineering. Special attention will be given to the design of soft, elastically-deformable machines and electronics that are primarily composed of elastomers, gels, fluids, gas, and other non-rigid matter. Specific topics will include the mechanics of hyperelastic solids, statistical mechanics of polymers and polymer composites, energy-based modeling techniques derived from the Laws of Thermodynamics, and their applications in modeling soft multifunctional material systems. Additionally, we will explore emerging paradigms in soft robotics, wearable computing, and human machine interaction, including material architectures for artificial muscles, stretchable electronics, and sensorized robotic skin. This course will include extensive reading with problem set assignments, a take-home exam, and final report. Students need familiarity with undergraduate-level solid mechanics, vector mechanics, thermodynamics, and ODEs

Prerequisite: 24-751

24-755 Finite Elements in Mechanics I

Fall: 12 units

The basic theory and applications of the finite element method in mechanics are presented. Development of the FEM as a Galerkin method for numerical solution of boundary value problems. Applications to second-order steady problems, including heat conduction, elasticity, convective transport, viscous flow and others. Introduction to advanced topics, including fourth-order equations, time dependence and nonlinear problems. 12 Units

Prerequisite(s): Graduate standing or consent of instructor

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-760 Robot Dynamics and Analysis**

Fall: 12 units

This course covers the dynamics of robotic systems with a focus on the mathematical structure of the dynamics and numerical analysis. Topics will start by reintroducing basic kinematics and dynamics in a more formal mathematical framework before moving on to contact conditions, friction, hybrid dynamical systems, simulation, and trajectory optimization. After the course students will be able to write simulation and optimization methods for analyzing robotic systems. Students should have taken a prior course in dynamics, and be comfortable with linear algebra, multivariable calculus, and programming in Matlab.

Prerequisites: 24-351 or 16-711

Course Website: <http://www.andrew.cmu.edu/user/amj1/classes/robotdynamics.html>**24-771 Linear Systems**

Fall: 12 units

Topics include review of classical feedback control; solution of differential and difference equations; Laplace and Z-transforms, matrix algebra, and convolution; state variable modeling of dynamic continuous and discrete processes; linearization of nonlinear processes; state variable differential and difference equations; computer-aided analysis techniques for control system design; state variable control principles of controllability, observability, stability, and performance specifications; trade-offs between state variable and transfer function control engineering design techniques; and design problems chosen from chemical, electrical, and mechanical processes. 4 hrs. lec. Prerequisite: An undergraduate course in classical control engineering or consent of the instructor.

Prerequisite: 24-451

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-774 Advanced Control Systems Integration**

Fall: 12 units

This course focuses on the practical implementation of feedback / feedforward controllers. The entire controller design process is presented, including system modeling and identification, compensator design, simulation, and hardware prototyping. This is a project-based course in which students complete the controller design process on a nonlinear, MIMO hardware system. The goal is train students on the system integration skills necessary for success in industry or experimental laboratory work.

Prerequisites: 24-677 Min. grade C or 24-771 Min. grade C

Course Website: <http://www.cmu.edu/me/>**24-776 Non Linear Control**

Intermittent: 12 units

Nonlinear Control (12 Units) This course provides an introduction to the analysis and design of nonlinear systems and nonlinear control systems; stability analysis using Lyapunov, input-output and asymptotic methods; and design of stabilizing controllers using a variety of methods selected from linearization, vibrational control, sliding modes, feedback linearization and geometric control. 4 hrs. lec.

Prerequisite: 24-771

24-780 Engineering Computation

Fall: 12 units

This course covers the practical programming and computational skills necessary for engineers. These include: (1) programming in C++, (2) visualization using OpenGL, (3) basic data structures, and (4) basic algorithms. The course covers computational techniques required for solving common engineering problems and background algorithms and data structures used in modern Computer-Aided Design, Computer-Aided Manufacturing, and Computer-Aided Engineering tools. The course also offers intensive hands-on computational assignments for practice of common applications.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-781 Engineering Computation Project**

Fall

24-781 This project course is the first section of the two-semester sequence of Computational Engineering Projects. The course provides the students with hands-on problem-solving experience by using commercial computational tools and/or developing their own custom software. Each student, individually or along with other students, will work on a project under the guidance of Carnegie Mellon faculty members and/or senior engineers from industry. Students may select a project topic from those presented by advising faculty members and/or industry engineers. Alternatively, a student may propose and work on his/her own project topic if he/she can identify a sponsoring faculty member or industry engineer.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)**24-782 Machine Learning and Artificial Intelligence for Engineers - Project**

Spring: 12 units

This course provides an open-ended computational project experience in artificial intelligence and machine learning. This course will enable student teams to design, develop and test data-driven computational algorithms. Course objectives are: - Gain experience in data sciences and data-driven methods for engineering. - Learn advanced programming and computational system design. - Learn project planning and management, project evaluation, teamwork, technical communication. The projects will target problems involving experimental, simulated or crowd-sourced data. Each project will aim to build an artificial intelligence or machine learning system that accomplishes one or more of the following: Identify patterns in data, establish a mathematical model for the input/output relationships, classify data into distinct categories, use existing data to synthesize new solutions to a synthesis problem. Team activities include three presentations, two written reports, a final technology demo, and one final report in the form of an archival publication.

Prerequisites: 10-601 Min. grade C or 24-787 Min. grade C or 10-701 Min. grade C or 15-781 Min. grade C

Course Website: <http://www.cmu.edu/me/>**24-784 Special Topics: Trustworthy AI**

Intermittent: 12 units

Innovations driven by recent progress in artificial intelligence such as deep learning and reinforcement learning, have shown human-competitive performance. However, as research expands to real-world cyber-physical autonomy, the question of safety is becoming a crux for the transition from theories to practice. This course will first review fundamental knowledge for trustworthy AI autonomy, including adversarial attack/defend, generative models, hierarchical Bayesian models, safe reinforcement learning, rare-event/few-shot learning, and robust evaluation. Then from the research perspective, students will explore the novelty and potential extension of various state-of-the-art trustworthy AI research and their implementation through a series of readings. Students will develop the ability to conduct research in teams. Knowledge and research skills learned in this course can be applied to self-driving, healthcare devices, assistant robots, and intelligent manufacturing. This course is devised for research-focused students who have backgrounds and interests in statistical machine learning, robotics and control, and human-machine interaction. Other interested students should contact the instructor to determine if it is a good fit for them.

24-785 Engineering Optimization

Intermittent: 12 units

Engineering Optimization Intermittent: 12 units This course introduces students to 1) the process of formally representing an engineering design or decision-making problem as a mathematical problem and 2) the theory and numerical methods needed to understand and solve the mathematical problem. Theoretical topics focus on constrained nonlinear programming, including necessary and sufficient conditions for local and global optimality and numerical methods for solving nonlinear optimization problems. Additional topics such as linear programming, mixed integer programming, global optimization, and stochastic methods are briefly introduced. Model construction and interpretation are explored with metamodeling and model reformulation techniques, study of model boundedness, constraint activity, and sensitivity analysis. Matlab is used in homework assignments for visualization and algorithm development, and students apply theory and methods to a topic of interest in a course project. Fluency with multivariable calculus, linear algebra, and computer programming is expected. Students who are unfamiliar with Matlab are expected to learn independently using available tutorials and examples provided. 4 hrs.lecture Prerequisites: None 19785 and 24785: 12-units including the team-based engineering optimization project 19685 and 24685: 9-units excluding the project Prerequisites: 21-341 and 21-259

24-787 Machine Learning and Artificial Intelligence for Engineers

Fall: 12 units

This course introduces fundamental machine learning and artificial intelligence techniques useful for engineers working on data-intensive problems. Topics include: Probability and Bayesian learning, generative and discriminative classification methods, supervised and unsupervised learning, neural networks, support vector machines, clustering, dimensionality reduction, regression, optimization, evolutionary computation, and search. The lectures emphasize the theoretical foundations and the mathematical modeling of the introduced techniques, while bi-weekly homework assignments focus on the implementation and testing of the learned techniques in software. The assignments require knowledge of Python including text and image input/output, vector and matrix operations, simple loops, and data visualization. Students must have undergraduate level experience with linear algebra and vector calculus.

Prerequisites: 15-112 and 21-341

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-788 Introduction to Deep Learning

Spring: 6 units

This course introduces the deep learning methodology. Students will learn about the basics of deep neural networks, and their applications to different tasks in engineering. Students will be able to apply Deep Learning to a variety of artificial intelligence tasks pertinent to different engineering problems. Neural Networks and Convolutional Neural Networks (CNN) and different variations of it will be taught. The fundamental knowledge and mathematics behind backpropagation and automatic differentiation will be discussed. Deep learning libraries such as Pytorch will be taught, and students will learn to use these libraries for developing deep learning models.

Course Website: <http://www.cmu.edu/me/>

24-790 Thesis Research

Intermittent

This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

24-791 Graduate Seminar

All Semesters

Graduate seminar speakers include faculty, students, and invited guests from industry and academia. Through seminars, students widen their perspectives and become more aware of other topics in mechanical engineering

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-793 Supervised Reading

Fall and Spring

This independent study is designed to give students an opportunity to explore pertinent subjects through faculty directed reading. Variable hrs. Prerequisite: Completion of "Supervised Reading" form acquired by your graduate MechE advisor; which includes permission of the instructor.

Course Website: <https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html> (<https://www.meche.engineering.cmu.edu/education/graduate-programs/>)

24-794 Master of Science Research

Fall and Spring

This course is designed to be a training opportunity in engineering research and associated professional activity. Content includes a series of investigations under the student's initiative culminating in comprehensive reports, with special emphasis on orderly presentation and effective English composition for Master of Science candidates. Variable hrs. Prerequisite: permission of the instructor.

Course Website: <https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html> (<https://www.meche.engineering.cmu.edu/education/graduate-programs/>)

24-795 PhD Internship in Teaching Counterpoint

Fall and Spring

A teaching assignment under the guidance of a faculty member for intermediate or terminal-level doctoral candidates. Typical activities include preparing and teaching recitations, preparing and teaching laboratory sessions, holding office hours, grading and preparation of quizzes, problem sets and other assignments, and assisting instructor with other activities associated with teaching a course. 24-795 is 12 units and offered in Fall and Spring (P/F). All non-native English speakers must conform to the university regulation on the TA language requirements.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-797 Thesis Research

Fall and Spring

This course is designed to give students enrolled in the Ph.D. program an opportunity to conduct extensive research over the course of their studies. Variable hrs.

Course Website: <http://www.cmu.edu/me/graduate/index.html> (<http://www.cmu.edu/me/graduate/>)

24-799 Practicum in Mechanical Engineering

All Semesters

The Department of Mechanical Engineering at Carnegie Mellon considers experiential learning opportunities important educational options for its graduate students. One such option is an internship, normally completed during the summer. If a student receives an internship, the Mechanical Engineering Department will add the internship course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 2-3 page report with supervisor signature detailing the work experience and including how the internship was related to Mechanical Engineering. After the report has been reviewed and approved, a letter grade will be assigned and these 3 units will count towards degree requirements. International students interested in registering for the practicum must also be authorized for Curricular Practical Training (CPT). Further information is available on the Office of International Education's website: www.cmu.edu/oie.

Course Website: <https://www.meche.engineering.cmu.edu/education/graduate-programs/index.html> (<https://www.meche.engineering.cmu.edu/education/graduate-programs/>)

24-887 Machine Learning & Artificial Intelligence for Engineers

All Semesters: 12 units

This course introduces fundamental machine learning and artificial intelligence techniques useful for engineers working on data-intensive problems. Topics include: Probability and Bayesian learning, generative and discriminative classification methods, supervised and unsupervised learning, neural networks, support vector machines, clustering, dimensionality reduction, regression, optimization, evolutionary computation, and search. The lectures emphasize the theoretical foundations and the mathematical modeling of the introduced techniques, while bi-weekly homework assignments focus on the implementation and testing of the learned techniques in software. The assignments require knowledge of Python including text and image input/output, vector and matrix operations, simple loops, and data visualization. Students must have undergraduate level experience with linear algebra and vector calculus. 24-887 is a remote version of the in-person course 24-787 and is exclusively for students enrolled in the AI / ML certificate program.

24-892 Locomotion Seminar

Intermittent

The CMU Bipedal Locomotion Seminar is a weekly meeting amongst students and professors who study bipedal locomotion using a variety of approaches. Each week, one graduate student participant gives a presentation on a topic of their choosing related to their research. We encourage discussion and interaction, especially from fellow students. Each meeting is intended to work like a small, informal conference discussion or workshop, providing students with new perspectives on their projects, practice presenting and answering questions, and a forum for meeting colleagues. We encourage participation from all interested students and faculty, including members of Carnegie Mellon, The University of Pittsburgh, and Disney Research Pittsburgh. Please join the waitlist and contact one of the instructors for admission.

Course Website: http://www.andrew.cmu.edu/user/amj1/locomotion_seminar.html

24-991 Professional Development for PhD students

Fall: 2 units

This course is the first in a sequence of two required courses where incoming PhD students learn research and professional communication skills that will benefit them throughout the PhD and in their careers. Topics covered include DEI and cross-cultural communication, reading and understanding technical publications, building the student/advisor relationship, working in teams, communicating by email, presenting for success, receiving and addressing critical feedback, and performing a literature review. The class intends to strengthen the PhD cohort and activities will often require group work and evaluation.

Engineering Minors for Non-Engineering Students

Biomedical Engineering Minor

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
kgaluska@andrew.cmu.edu
www.cmu.edu/bme/Academics/undergraduate-programs/minor.html (https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html)

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

| | |
|---|------|
| Minimum units required for minor: | 57 |
| 03-121 Modern Biology | 9 |
| or 03-151 Honors Modern Biology | |
| 42-101 Introduction to Biomedical Engineering | 12 |
| 42-202 Physiology | 9 |
| 42-xxx BME Elective I | 9-12 |
| 42-xxx BME Elective II | 9-12 |
| 42-xxx BME Elective III | 9-12 |

A BME Elective is defined as one of the following:

- One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.
- 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.
- Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological or medical content towards the minor requirements.

Engineering Studies Minor

(for non-engineering students)

Kurt Larsen, *Director*
Location: Scaife Hall 426

Carnegie Mellon undergraduate students enrolled in colleges other than engineering can complete a Minor in Engineering Studies in addition to their regular majors. Students pursuing this minor are required to complete courses from at least two different engineering departments in order to assure some breadth of exposure to engineering. In addition, the minor provides students the opportunity to pursue an in-depth concentration in a particular field of engineering.

For the Minor in Engineering Studies, students must complete five engineering courses as follows and must earn a cumulative QPA of 2.00 in these five courses. Students may declare the minor by contacting the director after they have successfully completed one introductory engineering courses (from list #1 below).

Requirements

- At least one and up to three of the following:

| | | |
|--------|--|----|
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 18-100 | Introduction to Electrical and Computer Engineering | 12 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 24-101 | Fundamentals of Mechanical Engineering | 12 |
| 27-100 | Engineering the Materials of the Future | 12 |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 06-100 | Introduction to Chemical Engineering | 12 |
| 49-101 | Introduction to Engineering Design, Innovation, and Entrepreneurship | 12 |
- Four engineering-centric courses of at least nine units each. Students must demonstrate both breadth and depth by taking courses from at least two of the below departments; and at least two courses from the same department.
 - Biomedical Engineering
 - Chemical Engineering
 - Civil and Environmental Engineering
 - Electrical and Computer Engineering
 - Engineering and Public Policy*
 - Materials Science and Engineering
 - Mechanical Engineering

Up to one of the following Robotics courses can count toward the ES minor. But it cannot be double-counted with the Robotics minor or double major.

| | | |
|--------|------------------------------------|----|
| 16-311 | Introduction to Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| 16-385 | Computer Vision | 12 |
| 16-421 | Vision Sensors | 12 |
| 16-474 | Robotics Capstone | 12 |

NOTE: The following courses may NOT be included as part of the minor in Engineering Studies.

| | | |
|--------|---|----|
| 06-262 | Mathematical Methods of Chemical Engineering | 12 |
| 12-201 | Geology | 9 |
| 12-421 | Engineering Economics | 6 |
| 15-213 | Introduction to Computer Systems | 12 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 18-200 | ECE Sophomore Seminar | 1 |

| | | |
|--------|---|----|
| 18-202 | Mathematical Foundations of Electrical Engineering | 12 |
| 18-213 | Introduction to Computer Systems for a core major requirement (e.g. CS minor) | 12 |
| 24-280 | Special Topics: C++ Programming for Engineers | 9 |
| 24-291 | Environmental Systems on a Changing Planet | 9 |
| 24-311 | Numerical Methods | 12 |
| 42-202 | Physiology | 9 |

Double counting of core courses in student's primary major is not permitted.

*Because of the nature of the courses offered by Engineering and Public Policy, only two EPP courses (including 19-101) can be used toward the minor requirements. Most EPP courses (19-xxx) are not permissible for the minor; students need special permission to use 19-xxx toward this minor and should contact the director for prior approval. Students interested in EPP coursework should consider the Technology and Policy minor instead.

Technology and Policy Minor

Deanna H. Matthews, *Associate Department Head for Undergraduate Affairs*
Location: Wean Hall 5215

The Technology and Policy Minor is administered by the Department of Engineering and Public Policy (EPP). The Technology and Policy Minor is designed to give students a basic understanding of the interactions between technology, society and policy and some project experience in problems involving technology and policy.

Pre-requisites

Students should have prerequisite knowledge in economics (73-102 Principles of Microeconomics or higher level economics course) and statistics (36-202 Methods for Statistics & Data Science or higher level statistics course) in order to pursue the Technology and Policy Minor.

Course Requirements

| | | |
|-----------|---|----|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-301 | Decision Making Methods for Engineers and Scientists or other approved Decision Science course | 9 |
| or 19-351 | Applied Methods for Technology-Policy Analysis | |
| 19-451 | EPP Projects I | 12 |
| xx-xxx | Two EPP Technology-Policy Electives | 18 |

EPP Technical Electives include courses that address problems at the society-technology interface and the means of analyzing these issues. A list of qualifying Technology-Policy electives is assembled each semester and is available from the EPP Department. Example Technology-Policy electives include:

| | | |
|--------|--|------|
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 19-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 19-429 | Climate Change Science and Solutions | 9 |
| 19-433 | Data Science for Technology, Innovation and Policy | 9 |
| 19-469 | Behavior, Decision and Policy | 9 |
| 19-639 | Policies of the Internet | 12 |
| 19-668 | Electric Vehicles: Technology, Economics, Environment and Policy | 12 |

Students must earn a cumulative QPA of 2.0 in all courses taken for the minor. Required courses taken for a student's primary major may not be counted toward the Technology and Policy Minor. Elective courses for a student's primary major or courses fulfilling general education requirements may be counted, however.

Information Security, Privacy and Policy Minor

Lujo Bauer, Director

Interdisciplinary minor offered by both CIT and SCS

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, they are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

| | | |
|--------|---|----|
| 17-331 | Information Security, Privacy, and Policy | 12 |
|--------|---|----|

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

| | | |
|--------|-------------------------------------|---|
| 17-333 | Privacy Policy, Law, and Technology | 9 |
|--------|-------------------------------------|---|

Students may substitute a 12-unit version of this course: 19-608, 17-333, or 95-818.

PRIVACY ELECTIVES

Complete a minimum of 9 units:

| | | |
|---------------|-----------------------------------|----|
| 19-534/17-334 | Usable Privacy and Security | 9 |
| 19-602/17-702 | Current Topics In Privacy Seminar | 3 |
| 17-731 | Foundations of Privacy | 12 |

TECHNOLOGY AND POLICY ELECTIVES

Complete a minimum of 9 units:

| | | |
|--------|---|----|
| 19-211 | Ethics and Policy Issues in Computing | 9 |
| 17-562 | Law of Computer Technology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-639 | Policies of the Internet | 12 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

| | | |
|-----------|--|------|
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-356 | Introduction to Cryptography | 12 |
| 19/17-303 | Cryptocurrencies, Blockchains and Applications | Var. |

| | |
|---|----|
| 19-534/17-334 Usable Privacy and Security | 9 |
| 18-334 Network Security | 12 |
| 18-335 Secure Software Systems | 12 |
| 18-435 Foundations of Blockchains | 12 |

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department.

In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Undergraduate Designated Minors in the College of Engineering

Overview

Undergraduate students in the Carnegie Institute of Technology can elect to complete an interdisciplinary Designated Minor in addition to their regular majors for B.S. degrees. Designated minors have been added to the curriculum of the Carnegie Institute of Technology to promote flexibility and diversity among the college's engineering students. Independent of a student's major, he or she is able to pursue a selected designated minor from the following list:

- Additive Manufacturing
- Audio Engineering
- Biomedical Engineering
- Colloids, Polymers and Surfaces
- Electronic Materials
- Global Engineering
- Materials Science and Engineering
- Mechanical Behavior of Materials

An engineering student may elect to complete a CIT designated minor. Generally, the student takes all the required courses in an engineering major but uses electives to take courses needed to fulfill the requirements of the designated minor. Upon completion of the requirements of a CIT designated minor and the engineering degree, the minor is a formally recognized on the student's transcript.

Each of the CIT designated minors is administered by a Program Committee consisting of faculty from all major engineering departments who serve as faculty advisors. Each Program Committee certifies the completion of requirements of the designated minor. But the student's major department is responsible for approving the degree with a designated minor after reviewing a student's entire academic record. Any substitution or departure from the published curriculum should be avoided. For example, non-technical courses may not be substituted for required technical courses or electives. Equivalent technical electives offered by a designated minor as substitutions for required courses in a major must be approved by the Head of the student's major department.

Although a student generally can complete a designated minor without increasing the number of required units for graduation, early planning in electing a designated minor is important. A student also may find that some minors are more compatible than others with his/her major because of different relations between various major and minor requirements. The requirements for these CIT designated minors are listed below.

Additive Manufacturing Minor

The objective of the Minor in Additive Manufacturing is to provide the student with a background in the engineering science that applies to additive manufacturing (also known as 3D printing), from part design through additive processes, to properties and component performance. Particular emphasis is given to metals additive manufacturing, due to its rapidly growing impact on manufacturing across multiple industries, and the need for talent in this area. The minor is open to students in all engineering majors.

Students may not use any given course to satisfy simultaneously requirements in both their enrolled major and in this minor. Graduate courses counted towards this minor may not be (double) counted for a graduate degree.

Minor Coordinators

Paige Houser, Academic Advisor

Departmental Contacts

| | |
|-------------------------------------|-----------------------------|
| Biomedical Engineering | Robert Tilton |
| Chemical Engineering | Robert Tilton |
| Electrical and Computer Engineering | Maysam Chamanzar |
| Engineering and Public Policy | Deanna Hart Matthews |

| | |
|-----------------------------------|------------------------|
| Materials Science and Engineering | Anthony Rollett |
| Mechanical Engineering | Jack Beuth |

Course Requirements

This minor requires a total of five (5) courses comprising of three core courses and two technical electives.

| Three Core Courses | | 36 units |
|--------------------|---|----------|
| | | Units |
| 39-601 | Special Topics: Additive Manufacturing Processing and Product Development | 12 |
| 39-602 | Additive Manufacturing and Materials | 12 |
| 39-603 | Additive Manufacturing Laboratory | 12 |

Two Technical Electives

To select acceptable technical elective course options, please speak with your departmental contact, or see <https://engineering.cmu.edu/education/undergraduate-programs/curriculum/additive-manufacturing-minor.html>.

Audio Engineering Minor

Tom Sullivan, *Director and Faculty Advisor*

This sequence is for candidates who are engineering majors with interest in and/or have background in music, recording, sound-editing and/or other music technology areas; or majors from any discipline in the university who have the above interests and who can meet the prerequisite requirements for the engineering courses in the minor.

Note: Students who do not have the requisite engineering/science/math background should investigate the Minor in Music Technology offered by the School of Music.

*** prerequisites 18-240 and 18-213.

Course Requirements

Minimum units required for minor: 73-79

The student must have taken the appropriate prerequisite courses for the listed courses.

Prerequisite Courses, 0-3 units

Beginning Piano is required of students who do not pass a piano proficiency test.

| | Units |
|--|-------|
| 57-103 Elective Studio (Beginning Piano Class) | 3 |

Music Courses, 43-49 units

Basic Harmony I is required of students who do not qualify for entrance into Harmony I, based on their scores on the theory placement test.

| | Units |
|---|-------|
| 57-101 Introduction to Music Technology | 6 |
| or 57-171 Introduction to Music Technology (self-paced) | |
| 57-149 Basic Harmony I | 9 |
| or 57-152 Harmony I | |
| 57-173 Survey of Western Music History * | 9 |
| 57-188 Repertoire and Listening for Musicians | 1 |
| 57-337 Sound Recording | 6 |

* co-requisite 57-188.

| (choose two of the courses below) | Units |
|---------------------------------------|-------|
| 15-322 Introduction to Computer Music | 9 |
| 57-338 Sound Editing and Mastering | 6 |
| 57-347 Electronic and Computer Music | 6 |
| 57-438 Multitrack Recording | 9 |

Technical Courses, 33 units

Other courses may be taken with the approval of the Audio Engineering Minor Advisor.

| | Units |
|---------------------------------|-------|
| 33-114 Physics of Musical Sound | 9 |
| 18-490 Electroacoustics ** | 12 |

** prerequisites 18-220 and 18-290.

| (choose one of the courses below) | Units |
|--|-------|
| 18-300 Fundamentals of Electromagnetics | 12 |
| 18-341 Logic Design and Verification | 12 |
| 18-370 Fundamentals of Control | 12 |
| 18-491 Digital Signal Processing | 12 |
| 15-210 Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-214 Principles of Software Construction: Objects, Design, and Concurrency | 12 |
| 18-320 Microelectronic Circuits + | 12 |
| 18-349 Introduction to Embedded Systems *** | 12 |

+ prerequisite 18-220.

Biomedical Engineering Minor

Kristin Kropf, *Undergraduate Program and Alumni Relations Coordinator, Biomedical Engineering*
kgaluska@andrew.cmu.edu
www.cmu.edu/bme/Academics/undergraduate-programs/minor.html (https://www.cmu.edu/bme/Academics/undergraduate-programs/minor.html)

The minor program is designed for students who desire exposure to biomedical engineering but may not have the time to pursue the Biomedical Engineering additional major. The program is open to students of **all** colleges and is popular among both engineering and science majors. In conjunction with other relevant courses, the program may provide a sufficient background for jobs or graduate studies in biomedical engineering. Students interested in a medical career may also find this program helpful.

The Biomedical Engineering minor curriculum is comprised of three core courses and three electives. The Quality Point Average (QPA) for courses that count toward the minor must be 2.00 or better. No course taken on a pass/fail or audit basis may be counted towards the minor.

Students who have questions or are interested in declaring Biomedical Engineering minor should contact Kristin Kropf (kgaluska@andrew.cmu.edu).

Requirements

| | |
|---|------|
| Minimum units required for minor: | 57 |
| 03-121 Modern Biology | 9 |
| or 03-151 Honors Modern Biology | |
| 42-101 Introduction to Biomedical Engineering | 12 |
| 42-202 Physiology | 9 |
| 42-xxx BME Elective I | 9-12 |
| 42-xxx BME Elective II | 9-12 |
| 42-xxx BME Elective III | 9-12 |

A BME Elective is defined as one of the following:

- One semester of 42-200 Sophomore BME Research Project, 42-300 Junior BME Research Project, 42-400 Senior BME Research Project or 39-500 Honors Research Project. The project must be supervised by a core or courtesy Biomedical Engineering faculty member and for 9 or more units. Research projects supervised by a courtesy Biomedical Engineering faculty member must have significant biomedical engineering relevance. Note that BME Research Project can only be count as one BME elective.
- 42-203 BME Laboratory (or the cross-listed version 03-206 for students in the Health Professions Program). Please note that priority for enrollment in 42-203 or 03-206 will be given to students who have declared the Additional Major in Biomedical Engineering. If sufficient room in the course remains after all majors have been accommodated in a given semester, students who have declared the Biomedical Engineering Designated Minor will be given the next priority for enrollment. If space still allows, other students will be enrolled.
- Any 42-xxx course with a course number greater than 42-300 and worth at least 9 units (excluding 42-300 and 42-400- see previous comment regarding BME Research Project).

Students can petition the Biomedical Engineering Undergraduate Affairs Committee to count non-BME classes that have significant biological or medical content towards the minor requirements.

Colloids, Polymers and Surfaces Minor

Professor Robert Tilton, *Director of CPS Minor*
Location: Doherty Hall A207C

The sequence of courses in the Colloids, Polymers and Surfaces (CPS) designated minor provides an opportunity to explore the science and engineering of fine particles and macromolecules as they relate to complex fluids and interfacially engineered materials. These topics are very relevant to technology and product development in industries that manufacture pharmaceuticals, coatings and paints, pulp and paper, biomaterials, surfactants and cleaning products, cosmetics and personal care products, food, textiles and fibers, nanoparticles, polymer/plastics, composite materials.

Course Requirements

Minimum units required for minor: 45

This minor requires a total of five classes with a minimum of 45 units. The following four courses are mandatory:

| | |
|--|---|
| 06-609/09-509 Physical Chemistry of Macromolecules | 9 |
| 06-607 Physical Chemistry of Colloids and Surfaces | 9 |
| 06-426 Experimental Colloid Surface Science | 9 |
| 06-466 Experimental Polymer Science | 9 |

In addition, the student must take one CPS related elective course from the following list:

| | |
|--|----|
| 06-612 Formulation Engineering | 12 |
| 06-610 Rheology and Structure of Complex Fluids | 9 |
| 09-502 Organic Chemistry of Polymers | 9 |
| 27-565 Nanostructured Materials | 9 |
| 27-477 Introduction to Polymer Science and Engineering | 9 |

Other CPS electives are possible but must be approved by the Director of the CPS minor, Professor Tilton

Electronic Materials Minor

Jim Bain, *Co-Director*
Lisa M. Porter, *Co-Director*
Paige Houser, *Academic Advisor*

Electronic materials are ubiquitous and essential in 21st century society. They underpin technologies that we rely on everyday - everything from communication, transportation, and lighting to commerce and entertainment. Advances in the synthesis, processing, and design of electronic materials are continuing to push boundaries towards more energy-efficient technologies, such as neuromorphic and quantum computing, long-range electric vehicles, AI, renewable energy sources, and other yet-to-be-discovered applications.

The Electronic Materials (EM) Minor is designed for students who have a keen interest in electronic materials, such as semiconductors, dielectrics and magnetics, and who are considering graduate school studies or careers pertaining to electronic materials industries. Students in the EM Minor will choose from a list of course electives from which they will learn about the physics, chemistry, synthesis, processing, design, characterization, and applications of a wide variety of electronic materials and devices.

Course Requirements

Minimum units for minor 54

54 Units From the Following Electives * :

| | |
|--|------|
| 27-100 Engineering the Materials of the Future (ECE students only) | 12 |
| or 27-201 Structure of Materials | |
| or 27-211 Structure of Materials (Minor Option) | |
| 18-100 Introduction to Electrical and Computer Engineering (MSE students only) | 12 |
| 27-202 Defects in Materials (ECE students only) | 9 |
| or 27-212 Defects in Materials (Minor Option) | |
| 27-432 Electronic and Thermal Properties of Metals, Semiconductors and Related Devices | 9 |
| 27-433 Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices | 9 |
| 27-445 Structure, Properties and Performance Relationships in Magnetic Materials | 9 |
| 27-533 Principles of Growth and Processing of Semiconductors | 6 |
| 27-542 Thin Film Technologies | 9 |
| 18-220 Electronic Devices and Analog Circuits | 12 |
| 18-300 Fundamentals of Electromagnetics | 12 |
| 18-310 Fundamentals of Semiconductor Devices | 12 |
| 33-225 Quantum Physics and Structure of Matter | 9 |
| xx-xxx An approved special topics or graduate level class pertaining to electronic materials | 6-12 |

| | | |
|--------|--|------|
| xx-xxx | An approved research project on electronic materials | 6-12 |
|--------|--|------|

*Students in ECE must take a minimum of 9 units in MSE, students in MSE must take a minimum of 9 units in ECE.

Global Engineering Minor

Treci Bonime, Director
Office: Scaife Hall 424

Many engineers work on international projects or for multinational companies. Carnegie Mellon is an international community, with a significant fraction of international students and many events featuring foreign speakers and cultural experiences. This minor is intended for engineering students interested in broadening their background in international experiences and global awareness and engagement.

Course Requirements

International Management (1 course)

Complete one course in international management or business such as:

| | | |
|--------|---|---|
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-381 | Marketing I | 9 |
| 70-430 | International Management | 9 |

Or approved equivalent

Regional Specialization (1 course)

Complete one course in non-US History, international politics, or literature in a single region of the world. See the list at <https://engineering.cmu.edu/education/undergraduate-programs/curriculum/global-courses-minors.html> (http://www.cit.cmu.edu/global/courses_degrees.html) below for examples (Note: Please consult with the Global Engineering director before planning your course schedule, as some course information may have changed).

Ethics (1 course)

Any ethics course that provides some exposure to international ethics issues such as:

| | | |
|--------|--|---|
| 70-332 | Business, Society and Ethics | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-244 | Environmental Ethics | 9 |

Or approved equivalent

Modern Languages

Demonstration of basic competency in a foreign language via one of the three options listed below:

- Complete one (1) Modern Languages course at the 200 level, with a minimum grade of C, or
- Achieve a score of 4 or higher in one foreign language Advanced Placement examination, or
- Demonstrate equivalent proficiency to the satisfaction of the Department of Modern Languages

Study/Work Abroad

Study or engineering internship work abroad for a semester or a summer. The region visited should be consistent with the language and regional culture/history studied.

Materials Science and Engineering Minor

Paige Houser, *Academic Advisor*
Location: Wean Hall 3317

The Designated Minor in Materials Science and Engineering provides the CIT student with a background in the field of Materials Science and Engineering.

This minor is open to all CIT students, with the exception of MSE majors. All required and elective courses are taught within the MSE Department.

Course Requirements

Minimum units required for minor 45

The minor requires a minimum of 45 units.

Prerequisites

Students wishing to take the MSE minor must have prerequisite thermodynamics and transport courses. The prerequisite MSE courses may be substituted for by a thermodynamics and transport course in another engineering discipline.

Core Courses (21 units)

| | | |
|--------|---|---|
| 27-211 | Structure of Materials (Minor Option) | 6 |
| 27-212 | Defects in Materials (Minor Option) | 6 |
| 27-227 | Phase Relations and Diagrams (Minor Option) | 9 |

The laboratories with these courses are not required as core but will be counted as elective units if desired.

Elective Courses (24 units minimum)

The student must select a minimum of 24 units from the following list:

| | | |
|--------|---|------|
| 27-100 | Engineering the Materials of the Future | 12 |
| 27-301 | Microstructure and Properties I | 9 |
| 27-570 | Polymeric Biomaterials | 12 |
| 27-477 | Introduction to Polymer Science and Engineering | 9 |
| 27-357 | Introduction to Materials Selection | 6 |
| 27-367 | Selection and Performance of Materials | 6 |
| 27-433 | Dielectric, Magnetic, Superconducting Properties of Materials & Related Devices | 9 |
| 27-432 | Electronic and Thermal Properties of Metals, Semiconductors and Related Devices | 9 |
| 27-421 | Processing Design | 6 |
| 27-445 | Structure, Properties and Performance Relationships in Magnetic Materials | 9 |
| 27-591 | Mechanical Behavior of Materials | 9 |
| 27-454 | Supervised Reading | Var. |
| 27-533 | Principles of Growth and Processing of Semiconductors | 6 |
| 27-555 | Materials Project I | Var. |
| 27-565 | Nanostructured Materials | 9 |
| 27-542 | Thin Film Technologies | 9 |
| 27-592 | Solidification Processing | 9 |
| 42-444 | Medical Devices | 9 |

Mechanical Behavior of Materials Minor

Program Contacts

Paige Houser, *Academic Advisor*

Paul S. Steif, *Mechanical Engineering*

An understanding of mechanical behavior is important to both the development of new materials and the selection of appropriate materials for many applications. The mechanical behavior of materials is best investigated and understood by integrating solid mechanics with the microstructural basis of flow and fracture. The purpose of this minor is to allow a formal basis for students to pursue an integrated approach to the mechanical behavior of materials.

Although this minor is open to all CIT students, only students in the departments of Civil Engineering, Materials Science and Engineering, and Mechanical Engineering can take advantage of the double counting permitted for some courses in their department majors. Students in other departments may have difficulty in fulfilling the requirements in four years.

Course Requirements

Minimum units required for minor 51-54

The minor requires six courses: three core courses, two solid mechanics courses, and one materials science course. In satisfying these course requirements, each student must take three out-of-department courses. Each student is required to complete three core courses:

Core Courses:

| | | |
|-----------|----------------------------------|------|
| 27-201 | Structure of Materials | 9 |
| 27-591 | Mechanical Behavior of Materials | 9-12 |
| or 27-791 | Mechanical Behavior of Materials | |
| 12-212 | Statics | 9 |
| or 24-261 | Mechanics I: 2D Design | |

Group A: Materials Science Courses

Each student must take one course from this list of Materials Science courses:

| | | |
|--------|--|----|
| 27-202 | Defects in Materials ¹ | 9 |
| 27-357 | Introduction to Materials Selection ² | 6 |
| 27-709 | Engineering Biomaterials | 12 |

¹ 27-202 cannot be used by MSE students to satisfy the requirements of the minor.

² 27-357 cannot be used by MSE students to satisfy the requirements of the minor.

Group B: Solid Mechanics Courses

Each student must take two of the following Solid Mechanics courses:

| | | |
|-----------|-------------------------|----|
| 12-231 | Solid Mechanics | 9 |
| or 24-262 | Mechanics II: 3D Design | |
| 12-635 | Structural Analysis | 12 |
| or 24-351 | Dynamics | |

Students should check with the director of the program or their faculty advisor for an up-to-date list of relevant courses that will count towards this minor. For more information, please consult the Undergraduate Course Catalog and the current Schedule of Classes.

College of Fine Arts

Mary Ellen Poole, Dean (CFA 100)

Kristen Kovak, Senior Associate Dean for Academics (CFA 100)
www.cfa.cmu.edu (<http://www.cfa.cmu.edu>)

Overview

The College of Fine Arts at Carnegie Mellon University was founded in 1905 as the first comprehensive arts learning institution in the United States. For 110 years it has educated outstanding artists, architects, designers, theater artists and musicians who have made important contributions to culture in the United States and the world. The alumni of the College of Fine Arts have shaped the worlds of television, stage, film, and electronic media; are collected in numerous international museums; have composed for and are performing in and conducting major symphony orchestras, choruses and opera companies throughout the world; have built notable buildings, pioneered innovative sustainable design strategies and created interactive software systems; created significant innovations in graphic and industrial design; and are professors and deans in major arts institutions.

The College of Fine Arts concentrates on the education of professionals in the arts in the broader context of Carnegie Mellon University. Beyond their education in their chosen field, through required and elective course work, students are involved with other disciplines within the College of Fine Arts and within the other colleges of Carnegie Mellon University. Further, the College's location in the Oakland District of Pittsburgh with its broad cultural resources (The Carnegie Museum of Art, the Carnegie Museum of Natural History, The Carnegie Library, the University of Pittsburgh, The Hillman Library, the Frick Fine Arts Building, and Phipps Conservatory and Botanical Gardens) places the College of Fine Arts at the center of a premier cultural environment.

The College of Fine Arts has a 9:1 student faculty ratio which provides a rigorous learning environment. It is a highly spirited federation of schools (Architecture, Art, Design, Drama and Music) made up of students and faculty who have an intense need to create and excel. Interacting among the schools, the University and the wider community are research centers such as the Frank-Ratchye Studio for Creative Inquiry, the Center for Building Performance and Diagnostics, Remaking Cities Institute, Center for Iranian Music, and the Center for Arts in Society. The intellectual and artistic life of the College is interwoven with a dense calendar of theater performances, concerts, exhibitions, film and media presentations and lectures by visiting artists, practitioners and scholars.

The College of Fine Arts offers a wide range of professionally oriented majors and minors in each of its schools. In addition, the College offers the Bachelor of Computer Science and Arts (BCSA), jointly with the School of Computer Science, the Bachelor of Humanities and Arts (BHA), jointly with the Dietrich College of Humanities and Social Sciences, the Bachelor of Science and Arts (BSA), jointly with the Mellon College of Science, the Engineering and Arts (EA) additional major, jointly with the College of Engineering, and the Master of Arts Management (MAM) and Master of Entertainment Industry Management (MEIM), jointly with the Heinz College of Public Policy and Management. These are presented only briefly below, but a complete listing of the graduation requirements for these programs may be found in the school descriptions later in this section and elsewhere in this volume.

Schools

School of Architecture

Office: CFA 201

The School of Architecture provides deep immersion in the discipline of architecture, intensified by the broader Carnegie Mellon culture of interdisciplinary innovation and creative inquiry. We define the discipline of architecture as the integrated pursuit of design creativity, historical perspective, social responsibility, technical expertise, and global environmental leadership. Though every School of Architecture student graduates with intensive architecture knowledge, no two graduates leave with the same education. In the twenty-first century, few architecture problems are straightforward. Our graduates excel in the roles architects have performed for centuries—and in new roles catalyzed by the depth and breadth of their education—to create and execute innovative solutions to a huge range of emerging global challenges. The school offers the following degree programs: Bachelor of Architecture (B.Arch), Bachelor of Arts in Architecture, Master of Advanced Architectural Design (MAAD), Master

of Architecture (M.Arch), Master of Science and Ph.D. in Architecture–Engineering–Construction Management (MSAECM/PhD-AECM), Master of Science and Ph.D. in Building Performance and Diagnostics (MSBPD/PhD-BPD), Master of Science and Ph.D. in Computational Design (MSCD/PhD-CD), Master of Science in Sustainable Design (MSSD), and Master of Urban Design (MUD).

School of Art

Office: CFA 300

The primary mission of the School of Art is to develop in the individual student the skills, knowledge, and commitment required to work as an artist in society. The four-year undergraduate program leads to a Bachelor of Fine Arts degree in Art. Concentrations within the art major are offered in four areas: 1) Painting, Drawing, Print Media and Photography; 2) Electronic and Time-Based Work; 3) Sculpture, Installation, and Site Work; and 4) Contextual Practice. A Master of Fine Arts degree in Art is also offered.

School of Design

Office: MM 110

The School of Design combines its professional program with a sound education in the liberal arts, leading to careers in many fields of design. It offers the following degrees: Bachelor of Design with concentrations in Communications, Products, and Environments; M. Design in Design for Interactions; M.P.S. in Design for Interactions; M.A. in Design; Ph.D. in Transition Design.

School of Drama

Office: PCA 220

The School of Drama offers a highly focused, world-class theatre education with thorough preparation for sustained careers and innovation in today's widely-varied entertainment industries. The undergraduate programs lead to BFA degrees in Drama, with focuses in Acting, Music Theatre, Directing, Dramaturgy, Design, Production Technology and Management; MFA programs are offered in Scene, Costume, Sound, and Lighting Design; Directing; Dramatic Writing; and Production Technology and Management.

School of Music

Office: HOA 102

The School of Music has as its goal the preparation of musicians for careers in performance, composition, conducting, music education and music technology. The programs provide the opportunity to study with world-class artists utilizing the best aspects of conservatory training in the context of a major research university, combining the educational with the intensely professional. The Bachelor of Fine Arts is offered in Music Composition, Music Performance, and Music and Technology (a joint degree with the School of Computer Science and the Electrical and Computer Engineering Department) with minors in Collaborative Piano, Conducting, Music Education, Music Performance, and Music Technology available. The Master of Music is offered in Composition, Conducting, Performance, Music Education, and Music and Technology (a joint degree with Computer Science and the Electrical and Computer Engineering Department).

Academic Standards

Grading Practices

Grades given to record academic performance in the College of Fine Arts are detailed in the catalog section entitled "Undergraduate Academic Regulations." All courses taught by the schools in the College of Fine Arts follow the standard letter grade system of the university. Responsibility for the grade given the student rests entirely with the instructor and the school concerned. A permanent grade may not be raised by taking a second examination. Students who wish to repeat a course already passed must obtain approval from the Dean of the College. At the time of approval, the Dean will decide in the light of circumstances whether the new grade or the old grade will be the official grade used as the computing factor for honors. Both grades, however, will appear on the official transcript.

Academic Actions

The College of Fine Arts reviews every CFA student's academic performance and progress towards graduation at the end of each semester. If a student's academic record falls below the standards outlined in their student handbook, they receive an academic action. These actions are designed to notify the student of specific academic and graduation requirements, outline goals for completion, and identify avenues of support to help them succeed.

A student who is not making satisfactory progress toward meeting course standards, or toward completing graduation requirements in their declared degree path, will receive an academic action. Each academic action will be reviewed by the relevant school's appointed reviewers and then confirmed by the CFA Academic Advisory Committee, which makes the final decision. The CFA Dean's office will disseminate the academic action letters directly to the students and their advisors via their CMU email.

Actions are assigned based on the most recent semester under review but include a cumulative review of a student's performance to date. The actions listed below may be given out of sequence, if a student meets the listed criteria.

Incomplete grades will be conditionally actioned by the default grades until the student completes the missing coursework. If the student does not complete their missing coursework by the faculty deadline agreed upon, their default grade and action will become permanent.

In order to support academic success, a student placed on an escalated academic action (probation and final probation) is not permitted to overload, undertake independent studies, or study abroad until they return to good standing. (See school/program handbook for specifics.)

WARNING

A Warning notifies the student of unsatisfactory performance and suggests that the student take steps to determine and correct the cause of the difficulty. Warnings are issued when one or more of the listed criteria are met within the semester under review:

- Receiving an R, D, or N in one elective or general education course;
- Failure to complete the semester's coursework as required by the student's major curriculum (one course);
- Failure to earn the minimum 2.00 quality point average.

If the student meets new actionable criteria in the following semesters, they may be assigned an escalated academic action.

PROBATION

Probation notifies the student of severe and/or continuous performance issues and suggests that the student take immediate steps to correct the cause of the difficulty. A previous action is not required. A student will be placed on Probation for failure to meet the academic and professional standards of their program including:

- Receiving one or more R, D, N, or W grade(s) in a required major course(s);
- Receiving two or more R, D, N, or W grades in elective or general education courses (either during one semester or over two semesters);
- Failure to complete the semester's coursework as required by the student's major curriculum (either two or more courses during one semester or over multiple semesters);
- Failure to earn the minimum 2.00 quality point average.

In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may continue on Probation or be assigned a successive academic action.

Students who are on academic Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to school/program handbooks for specific information.

FINAL PROBATION

A student will be placed on Final Probation for continued poor performance, or for continued failure to meet the requirements of their declared degree path, as outlined under the previous section on Probation. At least one previous action (warning and/or probation) must have been assigned prior to assigning final probation.

- Receiving multiple R, D, N, or W grades in a required major course(s) for two or more semesters;
- Receiving three or more R, D, N, or W grades in elective or general education courses over multiple semesters;

- Failure to complete the semester's coursework as required by the student's major curriculum (three or more semesters);
- Continued failure to earn the minimum 2.00 quality point average (two or more semesters).

In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may continue on Final Probation or be assigned a successive academic action.

Students who are on academic Final Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to school/program handbooks for specific information.

ACADEMIC SUSPENSION

All University Suspensions are a required, temporary leave from the university. This document covers **Academic Suspension** from the University. (For more information on *Disciplinary Suspension* or *Administrative Suspension* visit the student life sections on the university website:

<https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html>.

An Academic Suspension is intended to allow the student time to address or rectify any issues impeding or affecting their performance and progress towards meeting the academic standards of their declared degree path. The student is required to temporarily withdraw from the university for a specific period as defined in their suspension letter. Return from suspension is also subject to the conditions specified in the suspension letter and approval of the CFA Dean's office. At least two previous actions must have been assigned prior to assigning Academic Suspension.

A student will be placed on Academic Suspension for:

- Continued history of poor academic performance (three or more semesters);
- Continued lack of progress towards their declared degree (three or more semesters);
- Continued failure to meet the requirements of their declared degree path for continuing in the program; (three or more semesters)
- Failure to earn the minimum 2.00 quality point average. (three or more semesters)

A student returning from an Academic Suspension will be placed on Probation for the semester. In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may be considered for an Academic Drop.

A student who has been suspended from the university is required to leave the campus, including residence halls and fraternity/sorority houses, within a maximum of two days after the action and to remain off the campus for the duration of the time specified in the suspension letter. In addition, the student may not:

- register for courses at Carnegie Mellon
- attend classes
- live in residence halls or fraternity/sorority housing
- use campus facilities, including athletic facilities, library and computer clusters
- participate in student activities
- be members of student organizations
- have student jobs

(Note: students on academic suspension may still be eligible for a summer campus job if they accepted the job before they were suspended.) Go to the university policy webpage on student life for more information on a University Suspension:

<https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html>

ACADEMIC DROP

Students receive an Academic Drop from their School only when the student's academic progress is insufficient to warrant continuing in the current professional field of study. This action terminates the student's

enrollment in their current School/Program but is not intended to prejudice admission to another academic program within Carnegie Mellon University, or to another institution. Once a student receives an Academic Drop they may choose to:

1. Transfer to another CMU Department or School. Noting that the student must successfully transfer *prior* to resuming study at Carnegie Mellon.
2. Withdraw from Carnegie Mellon University. A link to the application for Withdrawal/Leave of Absence form is embedded with the letter notifying the student of this academic action, and is also available at www.cmu.edu/hub.

Appeal of Grades and Academic Actions

Refer to the School's Student Handbook for policy and procedure details.

Returning from Suspension

In order to return from a suspension, a student must have approval from the following administrators:

- *Academic Suspension* - associate dean;
- *Disciplinary Suspension* - dean of student affairs;
- *Administrative Suspension* - vice president for campus affairs or his/her designate.

Dean's Honor List

Each semester the College of Fine Arts recognizes those students who have attained outstanding semester quality point averages by naming them to the Dean's List. To be eligible, students must complete at least 36 factorable units and have no conditional, missing or failing grades in core classes at the time when final semester grades are recorded. The top 35% of eligible students in each of the College of Fine Arts schools are named to the Dean's List.

Graduation Requirements

Because of the special nature of work in the College of Fine Arts, the first year in all schools should be considered probationary, a period in which a student and faculty can evaluate professional promise in terms of the college's standards. Graduation from the College of Fine Arts follows the general university guidelines. As part of a student's qualification for an undergraduate degree, the equivalent of two terms of full-time work must be pursued under the direction of faculty members in the college during the period immediately prior to the degree award. Courses completed at other institutions will not be acceptable as terminal credit for a degree. Exceptions to this stipulation can be recommended by a school faculty in unusual cases, but the concurrence of the College Council is necessary before final approval of an exception can be given.

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate.

Other graduation requirements in the College of Fine Arts are described in the curriculum of each school. Further questions about specific course requirements and the total number of units required should be directed to the respective school advisors.

Other Regulations Affecting Student Status

Schedule Changes

Courses may be added or dropped within the times stated in the college calendar. No courses may be added or dropped after the stated deadline dates except with the approval of the student's School Head and the Dean of the College. (See Undergraduate Academic Regulations (p. 25) for Add/Drop procedures.)

Withdrawal/Leave of Absence

Please refer to the Student Leave Policy.

Transfer Students

Undergraduate students seeking transfer within or to any school of the College of Fine Arts must file an application with the School and proceed

with the established transfer application procedure, audition, portfolio review or ASAT requirements. Admission may dictate freshman status regardless of the student's prior college experience.

Materials

The college does not furnish students with any drawing materials, make-up materials, textbooks, or other expendable equipment except those in courses in which materials fees are charged to cover specific costs.

Retention of Students' Work

The college reserves the right to retain indefinite documentation of any student work the faculty may select. All work not retained by the faculty must be claimed at the time specified by the schools concerned. The college assumes no liability for student materials in its custody.

Student Defined Majors

The Student Defined Major program in the College of Fine Arts is designed for the exceptional student, whose area of artistic interest lies outside of any pre-existing program at the University. Student Defined Majors are expected to propose a comprehensive plan of study that combines all of their coursework into a singular focus for their research and artistic practice. To create a successful proposal, the student must engage in additional career and preparatory research outside of their normal coursework. Designing the independent degree program typically takes six months to one year to complete.

Students interested in pursuing this unique degree path should meet with their academic advisors to discuss feasibility. They will then work with the CFA Senior Associate Dean of Interdisciplinary Initiatives to ensure that their proposed coursework meets the rigorous requirements of a Carnegie Mellon degree. They will need approval from their academic advisor, faculty mentor(s), relevant Head(s) of School, (Senior) Associate Dean(s), and the Vice Provost for Education. If the proposal is approved and the student has successfully met the requirements of the new major, the degree conferred at graduation will be a *Bachelor of Arts with a Student Defined Major: *approved title**. The CFA Office of the Dean, in consultation with the academic advisor, will determine final certification of the degree. Note that all academic actions and CFA policies still apply to Student Defined Majors.

To apply for a Student Defined Major in the College of Fine Arts, one:

1. Must be a student in good standing at the University.
2. Must have successfully completed at least one semester of study and have at least two semesters left prior to their intended date of graduation.
3. Must have a cumulative QPA of 2.75 or better. (A student whose QPA is under 2.75 may still submit a proposal, but is strongly advised against it. If the proposal is accepted by the CFA Senior Associate Dean of Interdisciplinary Initiatives, the student must apply for transitional status for the following semester and will have only one semester to improve his or her QPA to the 2.75 minimum. If the student is not successful in raising the QPA to the 2.75 minimum they will not be permitted to continue with the Student Defined Major. They must either be re-admitted back into their old program or seek admittance into another department or college.)
4. Must have a faculty mentor in the College of Fine Arts who has agreed to mentor the student through the completion of the degree. This mentor should be from the school where the student is taking the majority of their courses, and be approved by the CFA Senior Associate Dean of Interdisciplinary Initiatives. If a student wishes to work extensively across colleges, they will need a faculty advisor(s) from their additional area(s) of concentration as well as approval from an Associate Dean of each college involved.
5. Must successfully complete the proposal process and submit all approved documentation with necessary signatures to the CFA Office of the Dean, CFA 100, by May 1 to be effective in the fall semester, and by October 1 to be effective in the spring semester. (Proposals that come in after these dates will be considered, but may not be able to be processed until the following semester.)

Student Organizations

Professional and honorary societies for students in the College of Fine Arts are the American Institute of Architects, Architecture Peer Mentors, Architecture Student Advisory Council, the Design League, American Institute of Graphic Arts (AIGA), Industrial Designers Society of America (IDSA), United States Institute for Theatre Technology (USITT), Phi Mu Alpha Sinfonia (music fraternity for men), Sigma Alpha Iota (music sorority for women), Pi Kappa Lambda (honorary for students in music) and the Music Educators' National Conference.

BXA Intercollege Degree Programs

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA), BACHELOR OF HUMANITIES AND ARTS (BHA), BACHELOR OF SCIENCE AND ARTS (BSA), ENGINEERING AND ARTS (EA) ADDITIONAL MAJOR

M. Stephanie Murray, *Director & Academic Advisor*
Location: HOA 211

www.cmu.edu/interdisciplinary (<http://www.cmu.edu/interdisciplinary/>)

The **Bachelor of Computer Science and Arts** (BCSA) is a four-year intercollege degree-granting program designed for students interested in pursuing fields that comprehensively meld technology and the arts through courses offered in the College of Fine Arts and the School of Computer Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the School of Computer Science, and free electives.

The **Bachelor of Humanities and Arts** (BHA) is a four-year intercollege degree-granting program designed for students interested in blending studies in the College of Fine Arts and the Dietrich College of Humanities and Social Sciences. The BHA degree combines a general education requirement, a concentration of courses in the College of Fine Arts, a concentration of courses in the Dietrich College of Humanities and Social Sciences, and free electives.

The **Bachelor of Science and Arts** (BSA) is a four-year intercollege degree-granting program designed for students interested in combining studies in the College of Fine Arts and the Mellon College of Science. It combines general education requirements, a concentration of courses in the College of Fine Arts, a concentration of courses in the Mellon College of Science, and free electives.

The **Engineering and Arts** (EA) additional major is an interdisciplinary program designed for College of Engineering students interested in developing their skills and interests in an area of the College of Fine Arts while retaining their full engineering curriculum and licensure. It combines a BXA course requirement and a concentration of courses in the College of Fine Arts with a student's primary engineering major.

Please refer to Interdisciplinary Programs (p. 893) in this catalog for details.

The Master of Arts Management Program

Location: 1115 Hamburg Hall

The search for both increased support and larger audiences has intensified over the last decade and now, more than ever, arts organizations seek skilled managers. To meet this need, the College of Fine Arts and the Heinz College's School of Public Policy and Management jointly developed the Master of Arts Management (MAM) Program to provide strong leadership in theater companies, dance companies, orchestras, opera companies, museums, galleries and arts policy organizations. In addition to the traditional two-year graduate degree structure, the Master of Arts Management Program provides undergraduate students the opportunity to complete the Bachelor of Fine Arts and Master of Arts Management degrees within a period of five years through the Heinz College's Accelerated Masters Program (AMP). MAM Program alumni can be found managing music and arts service organizations; marketing orchestras, theaters and dance companies; fund-raising for museums, opera companies, ballet companies and public television stations; and managing the finances of university arts departments and private businesses working in the arts and entertainment industry.

College of Fine Arts Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

62-002 CFA Elective

Intermittent: 9 units
TBA

62-104 Design Ethics & Social Justice in Architecture

Fall and Spring: 3 units

This course is aimed at first year architecture students as an introduction to social justice and design ethics. The course will explore how architecture relates to the human experience, human labor, and human rights; how the economic, political, and cultural contexts in which architects work contribute to issues of inequity; and what responsibilities architects and designers have to assure a greater sense of social justice for all. We will start by examining the traditional norms for the "standard" human body in design. Then will explore the meaning of identity (including race, class, gender, ethnicity), economic class and privilege. We will continue by exploring social justice, activism, climate change, colonialism and historically racist urban practices. Throughout the course, we will discuss how architecture is embedded in these issues and how architects might address these issues in current and future practice, both as citizens and as designers. This course includes lectures, weekly reading responses, and small group discussions. Class attendance and participation is required.

62-106 Architecture and the Arts

Fall: 9 units

This interdisciplinary course explores the entangled relationship between architecture and the arts, and their struggle between autonomy and engagement. It will be structured around a series of themes, drawings, and writings that reveal architecture's constantly changing involvement with art, culture, society, and related disciplines. The course functions both an introduction to Architecture as Art for a general audience, as well as a critical introduction to architectural thinking and theory for architecture majors. The course will include slide lectures, readings, reading reports, discussions, and a series of research exercises to engage architecture and art more critically, and an exam. We'll examine the common roots, disparate characters, and inter-twined histories of architecture and the arts. We'll investigate not just buildings and art works, but ideas, drawings, images and other representations involved in the construction and reception of architecture that often relate closely to the arts. We'll look at shared terms like composition, rhythm, studio, and form. We'll define architecture in relation to categories such as fine and applied arts, high and low arts, visual and performing arts, and relate these to broad categories such as design, visual culture, and the liberal arts. We'll ask "why" we make architecture and art, rather than "how," and discuss how the human need for expression and meaning can augment the technical and constructed value of mere making or building. We'll debate how the discipline of architecture has been, and can continue to be framed as a fine art, but also act as a service profession, a political tool, a technical expertise, a research endeavor, or as a mode of cultural discourse.

62-122 Digital Media I

Fall: 6 units

This course will engage in an overview of foundational workflows in digital media regarding two-dimensional representation techniques for spatial design processes. The course is divided into two topics with one assignment each: Technical Drawing and 2D Graphics. Students are required to submit work at the end of each class, in addition to self-guided work outside of class times: satisfactory completions of the two assignments, specific Lynda tutorials, final project, and final portfolio are required for the successful completion of the course. Through these deliverables, the course will inquire issues of 2D representation as it pertains to the effective communication of technical and conceptual information in spatial design processes. With digital media, designers now have an arsenal of tools that can subvert and augment traditional means of representation with exponentially greater fidelity and efficiency. Students will have an opportunity to practice these values and favor hybrid approaches that strive to blur the boundaries of analog and digital media, so as to learn how to be versatile in leveraging all forms of media for the design task at hand. Students are required to bring their own laptop computers with AutoCAD, Photoshop, Illustrator, and InDesign installed.

62-123 Digital Media II

Spring: 6 units

This is the second course in a two-course sequence that introduces students to a broad range of architectural drawing techniques and practices that document, communicate, and generate design possibilities. The course situates modes of representation within a rich disciplinary tradition, as well as within adjacent fields of discourse on visual culture and epistemology. This second instantiation expands the foundational skills established in 62-122 by surveying select, contemporary modes of digital production and communication especially as situated between design disciplines and adjacent practices in the sciences, the animation and gaming industries, digital forensics and archaeology, artificial intelligence and other modes of cultural production. The course also challenges students to establish a visual agenda of their by referencing and critiquing chosen practices and styles within contemporary architectural media.
Prerequisite: 62-122

62-125 Drawing I

Fall: 6 units

62-125 is an introductory course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through freehand drawing. A parallel objective is fostering visual literacy: the ability to use line and tonal values to represent architectural space. Topics covered are contour drawing, freehand perspective, axonometric projection, and tonal drawing in charcoal. The course concludes with a final project conducted jointly with 48-100, first-year architectural design.

62-126 Drawing II

Spring: 6 units

The central learning objective of Drawing II is building a capacity for visualizing three-dimensional space through freehand drawing. It has two secondary objectives: using line, tone and color to represent architectural space and architectural proposals. The course has four parts 1) free-hand and constructed perspective, 2) shade and shadow and chiaroscuro drawing in charcoal and colored pencil, 3) color drawing in pastel. 4) a final project combining freehand drawing, color work in Photoshop and a 3D digital model. Prerequisite: 62-125 or permission of the instructor.
Prerequisite: 62-125

62-141 Black and White Photography I

Fall and Spring: 10 units

This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art and #8212; what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Lab fee and 35mm manual camera required. Each student is responsible for the cost of paper and film.

62-142 Digital Photography I

Fall and Spring: 10 units

This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites.

62-150 IDEATe Portal: Introduction to Media Synthesis and Analysis

Fall: 10 units

To view the different section topics, visit courses.ideate.cmu.edu/62-150. Technologists, artists, and designers are engaging in new, interdisciplinary modes to consume, create, and reuse media. To do this, they thoughtfully collaborate and critically reflect on media creation, distribution, participation, interaction, and how media affects the audience. In this course, students will challenge themselves to work in these new modal contexts by thinking critically in a genre of exploration. They will formulate the intent of their creative work, articulate relationships to art/design practice and theory, and respond insightfully to creative, media-rich outcomes. The class will introduce core concepts through foundational texts, in-class exercises, collaborative projects, and group critique. Through hands-on media exploration, students will ground concepts such as embodiment, emergence, composition, participatory interfaces, and mediated experiences. Section A will be an Introduction to Textile Media. Section B will be an Introduction to Mediascapes: 2D to 3D Spatial Environments. For more detail on these sections, please visit courses.ideate.cmu.edu/62-150

Course Website: <https://courses.ideate.cmu.edu/62-150> (<https://courses.ideate.cmu.edu/62-150/>)

62-207 IDEATe: Variational Geometry I

Fall: 6 units

This course will introduce concepts and strategies for the modeling and development of complex computational geometry for 3D printing purposes and introduce algorithmic thinking using the Rhinoceros McNeel platform and Grasshopper plugin. This course is intended for students with no or little 3-D modeling skills to advance their abilities in modeling, digital prototyping and visual communication.

Course Website: <http://ideate.cmu.edu/about-ideate/departments/college-fine-arts/ideate-variational-geometry-i/>

62-225 Generative Modeling

Fall and Spring: 9 units

This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encouraged to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

62-239 Reading Pictures, Writing Photography

Intermittent: 9 units

Through photography's history, writers have sought to identify what is special about photography, the medium's essential characteristics, and what happens when photographs make something visible. In this course students will engage critically with photographs and photography through classic and contemporary texts on photography, and by producing their own writing. Students will become familiar with significant photographers and key issues raised around photography and develop their own critical and authorial voices. Readings include pieces by Roland Barthes, Walter Benjamin, Susan Sontag, Hito Steyerl, Rebecca Solnit, Teju Cole, and many others.

Course Website: <http://cfaphoto.cfa.cmu.edu/classesf17.html>

62-241 Black and White Photography II

Fall and Spring: 10 units

Black and White Photography II continues developing your technical skills in analog photography by introducing medium and large format cameras and prints. Large format view cameras remain the state of the art in control and quality in both film and digital photography. These cameras as well as unusual panoramic and pinhole cameras will be supplied. This course emphasizes aesthetic development and personal artistic growth through individual tutorials and group critiques, and will help to build professional level photography skills. Additional topics include digital printing and negative scanning, advanced monotone printing methods, and a focus on exhibition and folio presentation.

Prerequisites: 62-141 or 60-141

62-245 Portrait Photography

Intermittent: 10 units

Portraiture maintains a unique standing in photography for its direct and collaborative relationship between an individual and a photographer. This course will examine this relationship and the larger contexts which provide the conceptual framework for deriving meaning and understanding from an image of another person. We will study the theoretical and practical aspects of portrait photography in both studio and environmental settings, providing students with an understanding of the genre by developing both technical and conceptual skill sets. Students will utilize analog and digital equipment, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation. Students will gain knowledge in the development of portraiture through the work of notable figures in the medium's history and contemporary field, including August Sander, Dorothea Lange, Walker Evans, Dawoud Bey, Milton Rogovin, Rineke Dijkstra, Zoe Strauss, Susan Lipper, Justine Kurland, Stefan Ruiz, Larry Sultan, Carrie Mae Weems, Roy DeCarava and Alec Soth. Class discussions, readings and critiques will provide an outline for completing both single and serial image assignments.

Course Website: <http://cfaphoto.cfa.cmu.edu/classesf17.html>

62-247 Introduction to Hot Glass I

Fall and Spring: 3 units

In this introductory class, learn to gather clear molten glass from the furnace and then shape it into various forms, from paperweights to simple blown shapes, such as cups and bowls. Instruction focuses on a team approach to glassblowing, with an emphasis on safety, proper tool use, basic techniques, and materials. You'll never drink from a glass again without appreciating the energy and detail that went into making it! Little to no hot shop experience is required. You may also wish to take this class a second time in order to continue to develop and refine basic skills before moving on to Hot Glass 2. Each time you take it, your skill level, confidence, and passion for glass will grow. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is \$300. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: <https://www.pittsburghglasscenter.org/>

62-275 Fundamentals of Computational Design

Fall and Spring: 9 units

As analog mechanisms; as metaphors; as bodily extensions or prosthetics; as material systems; as building envelopes; as partners or slaves? of humans. This course takes computers outside the box and out on a journey of discovery revealing computation as the connective tissue encompassing multiple facets of architectural practice and experience. Addressing conceptual and practical aspects of the relationship between computation and design, the course explores the fundamentals of generative and rule-based systems for designing and making, simulation, and responsiveness, along with basic approaches to creative data processing, representation, and realization. The course offers a holistic view of computation, exploring the different roles computing plays in the design of our built environment. Organized in two-week modules, the course explores six themes, each combining historical insight, architectural examples, and hands-on design exploration.

Prerequisite: 48-100

62-314 The Art of Personal Finance

Fall and Spring; 6 units

Money is an inevitable part of our everyday lives. Managing the money we earn and living within our means is essential to ensure that we have the freedom to do what we want to do with our lives. However, even if we successfully eliminate debt and save for the future, true financial freedom will not exist unless we have a plan to guide us on our way. In this course, students will create a simple one-page financial plan that they can use to guide them through their next several years as they cultivate the skills that will ensure their artistic success. Additionally, they will develop the tools needed to support the execution of the plan and create a sourcebook of information they can refer to in the future as their lives (and their financial plans) change.

62-315 Shaping Environments: Experiments in Geometry and (Waste)Matter

Fall

Shaping Environments is a design-research seminar that explores alternative material formations beyond our current petrochemical reality. Using digital environments and computational tools, such as photogrammetry, depth-map texture modeling, AI workflows, and 3D printing, we will experiment with shaping new hybrid material systems. Using resources, such as food and/or construction waste, our goal is to propose new material paradigms that embrace ecological thinking and environmental stewardship through physical prototyping.

62-347 Hot Glass II

Fall and Spring; 3 units

Enroll in Hot I and build on your existing skill set and expand your creative potential. Refine and diverge from the standard cup and bowl shape in the first few weeks before moving on to more complex forms. Explore basic color application methods and learn how to troubleshoot common problems. It is recommended that all students take this class a second time in order to continue to develop and refine basic skills before moving on to Advanced Hot Glass. Hot I, 24 hours of hot shop experience, or instructor permission is required. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is \$300. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Prerequisite: 62-247

Course Website: <https://www.pittsburghglasscenter.org>**62-360 Photographers and Photography Since World War II**

Spring; 9 units

Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences.

62-362 IDEATe: Electronic Logics && Creative Practice

Intermittent; 12 units

Electronic Logics and amp; and amp; Creative Practice investigates the fundamentals of electronic computation as metaphors for art and interaction. Students explore technology through a creative lens, as conceptual and physical material to be manipulated and synthesized, by examining the basis of digital computation alongside contemporary and new media art practices. There are three main units: Gates (the logical building blocks of computers), Flow (ways in which signals "flow" through physical and electronic systems), and Arrows (the stacked layers of indirection used in modern computer systems). These major themes are addressed through lecture, readings, and the creation of individual and collaborative works. Throughout the semester students complete a series of quick thematic exercises and three larger-scale projects; these works are reviewed through meetings, group critique, and documentation. Our toolbox includes 7400-series logic chips, the Arduino electronics platform, software, wood, laser cut acrylic, found objects, props, projections, and glue. We address technical engineering subjects (e.g. Karnaugh maps) alongside art and performance theory. Students deepen conceptual skills while increasing the scale and ambition of creative output. The course culminates in an end-of-semester showcase where students publicly exhibit their work.

62-371 Photography, The First 100 Years, 1839-1939

Fall; 9 units

Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

62-450 Introduction to Flameworking

Fall and Spring; 3 units

Learn flame shop essentials and a variety of creative techniques while working with a solid rod of glass. Using a propane/oxygen torch, students will learn to melt and manipulate glass into little treasures, such as beads, pendants, marbles, chains, and sculptures. Over the course of 8 weeks, learn color application, hand control, and annealing. The instructor will also provide one-on-one troubleshooting. Class tuition includes 2 hours of open-studio time to be used during the 8-week course period. This will help you become familiar with the studio itself and learn the process of studio rental beyond class hours. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is \$190. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: <https://www.pittsburghglasscenter.org>**62-459 Intro to Stained Glass**

Fall and Spring; 3 units

Explore the possibilities of colorful stained glass. In this introductory course, you will learn the basics for working with flat glass; cutting, grinding, foiling, and soldering. You will explore the famous Tiffany Method of construction and work with provided patterns to create a beautiful stained-glass pane ready for display! This class is designed for beginners and is a pre-requisite for Intermediate and Advanced Stained Glass. Registration for Pittsburgh Glass Center classes can only be done on or after your scheduled registration day. Spaces are limited. Registration is done on a first come, first served basis. Please email Stefanie McGowan (stefanim@andrew.cmu.edu) for more information and to register. Course fee is \$240. Not eligible for PCHE Cross Registration. Course taught at the Pittsburgh Glass Center.

Course Website: <https://www.pittsburghglasscenter.org>**62-478 IDEATe: digiTOOL**

Fall and Spring; 9 units

This course serves as an introduction to the fundamental concepts, processes, and procedures to utilize digital and traditional equipment within the IDEATe facilities in Hunt Library. After completion, participating students should leave with a thorough understanding of 3D modeling, 3D printing, laser cutting, engraving, and basic finishing techniques. Students will learn how to operate in a safe, responsible, and efficient manner. This comprehension and experience proves useful for all creative disciplines, and participants are certified for future fabrication equipment access.

Minors Offered by the College of Fine Arts

The College of Fine Arts offers minors in Architecture, Art, Design, Drama, and Music to students from other colleges at Carnegie Mellon University. These minors allow students at Carnegie Mellon to take courses and develop a direction for electives in any of the five schools in CFA. Students in the College of Fine Arts may also earn minors outside of their major within other schools in the College. They may also study any of the minors offered by the other colleges to the University at large, thus taking advantage of the broad educational opportunities available at Carnegie Mellon University.

Minors Offered by the College of Fine Arts:

- Architectural Design Fabrication (available only to B. Arch candidates)
- Architectural Representation and Visualization (available also to B. Arch candidates)
- Architectural Technology
- Architecture
- Architecture History (available also to B. Arch candidates)
- Art
- Building Science (available only to B. Arch candidates)
- Collaborative Piano (available only to Piano majors in the School of Music)
- Conducting (available only to students in the School of Music)
- Design
- Drama
- History of the Arts
- Media Design (IDeATe)
- Music
- Music Education (available only to students in the School of Music)
- Music Technology
- Music Theory
- Musicology
- Photography
- Sonic Arts (IDeATe)

Guidelines for students are: 1) except where so designated, CFA students are not eligible to earn a minor in their own school; students from outside CFA may earn a minor in any school in CFA; 2) faculty advisors in the student's home school (in consultation with the academic officer of the other unit involved) will advise students as to the structuring of the courses in each minor; 3) a minor is not to be considered an overload; rather, through the assistance of faculty advisors it should be integrated into a student's overall units required for graduation; 4) the advisors will also monitor the student's development in these minors and keep records in their files which indicate the fulfillment of the course requirements in the minors, as well as in the majors in the student's own school. Courses listed as possible for the minors may be available, but not all courses are offered every semester. Students should consult with their advisors.

Students interested in earning a minor in any of the CFA schools should contact: Architecture: Heather Workinger; Art: Keni Jefferson; Design: Melissa Cicozi; Drama: Valeria McCrary; Music: Sharon Johnston; IDeATe: Kelly Delaney.

Architecture Minors

For the most up-to-date list of architecture-related minors, see: <https://soa.cmu.edu/minors> (<https://soa.cmu.edu/minors/>).

Minor in Architecture

Available to non-architecture majors only (minimum 54 units total)

This sequence is for candidates who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture.

Prerequisite Courses 9 units

| | | |
|--------|--|---|
| 79-104 | Global Histories or course 62-110 or 62-106 | 9 |
|--------|--|---|

Required Courses 19-24 units

| | | |
|--------|--|----|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 or 48-095 Spatial Concepts for Non-Architecture Majors | 12 |
| 48-240 | History of World Architecture, I | 9 |

Elective Courses* 26-31 units

| | | |
|--------|---|---|
| 62-125 | Drawing I | 6 |
| 62-126 | Drawing II | 6 |
| 62-122 | Digital Media I | 6 |
| 62-123 | Digital Media II | 6 |
| 48-215 | Materials & Assembly | 9 |
| 48-324 | Structures/Statics | 3 |
| 48-380 | Real Estate for Architects | 6 |
| 48-381 | Issues of Practice | 6 |
| 48-383 | Ethics and Decision Making in Architecture | 6 |
| 48-xxx | Architecture History (Pre-Approval of coursework required) | 9 |
| 48-xxx | Architecture Elective (Pre-Approval of coursework required) | 9 |

Minimum Units: 54

*Students should consult the Architecture advisor regarding elective choices.

Minor in Architecture History

Available to both architecture majors (63 total units total) and non-architecture majors (54 total units total)

This sequence is intended for candidates interested in the history of architecture in its many manifestations, including high style and vernacular buildings, western and non-western traditions, built and theoretical works, and rural to urban contexts. Non-architecture majors are required to take 54 units of architectural history. Architecture majors wishing to minor in Architectural History must fulfill the three core required courses in architectural history, plus four additional architectural history electives, for a total of 63 units. Students wishing to pursue the minor should meet with the Architecture advisor to determine if a course is eligible.

Required Courses 18 units

| | | |
|--------|----------------------------------|---|
| 48-240 | History of World Architecture, I | 9 |
| 48-241 | History of Modern Architecture | 9 |

Selective Courses 36 units/45 units

Students should consult the Architecture advisor regarding elective choices.

Minimum Units: 54 (non-architecture majors)

Minimum Units: 63 (architecture majors)

Minor in Architectural Representation and Visualization

Available to both architecture majors (63 total units total) and non-architecture majors (54 total units total)

The Minor in Architectural Representation and Media is intended for those students that want to deepen their knowledge in architectural representation and media and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Computational Design (MSCD). It is earned by completing the four required media courses and then an additional three elective courses in these areas. Architecture majors wishing to pursue a Minor in Architectural

Representation and Visualization must complete the required 33 units and at least an additional 30 units to fulfill the minor for a total of 63 units.

Required Courses 24 units

| | | |
|--------|------------------|---|
| 62-122 | Digital Media I | 6 |
| 62-123 | Digital Media II | 6 |
| 62-125 | Drawing I | 6 |
| 62-126 | Drawing II | 6 |

Selective Courses 30-39 units

| | | |
|--------|--|----|
| 48-568 | Advanced CAD, BIM, and 3D Visualization | 9 |
| 48-724 | Scripting and Parametric Design | 10 |
| 48-3xx | Architectural Drawing Elective (Pre-Approval of coursework required) | 9 |
| 48-xxx | Architectural Representation/Visualization Elective: (Pre-Approval of coursework required) | 9 |
| 48-xxx | Architectural Representation/Visualization Elective: (Pre-Approval of coursework required) | 9 |

Minimum Units: 54 (non-architecture majors)

Minimum Units: 63 (architecture majors)

Minor in Architectural Technology

Available to non-architecture majors only (minimum 54 units total)

This sequence is for candidates who intend to develop intellectual links to the technical aspects of the profession.

Prerequisite Courses 22 units

| | | |
|--------|------------------------------------|----|
| 33-141 | Physics I for Engineering Students | 12 |
| 21-120 | Differential and Integral Calculus | 10 |

Selective Courses 32 units

| | | |
|--------|---|---|
| 48-116 | Introduction to Building Performance | 3 |
| 48-215 | Materials & Assembly | 9 |
| 48-324 | Structures/Statics | 3 |
| 48-315 | Environment I: Climate & Energy in Architecture | 9 |
| 48-432 | Environment II: Design Integration of Active Building Systems | 9 |
| 48-752 | Zero Energy Housing | 9 |
| 48-xxx | Architectural Technology Elective (pre-approval required) | |

Minimum Units: 54

Minor in Building Science

Available to architecture majors only (minimum 54 units total)

The Minor in Building Science is intended for those students that want to deepen their knowledge in the building sciences and for those who are interested in gaining advanced placement (AMP) in the M.S. programs offered by the School in the areas of Building Performance & Diagnostics (MSBPD) and Sustainable Design (MSSD). It is earned by completing the two required building technology and three environmental science courses and then an additional three elective courses in the building sciences.

Required Course 12 units

| | | |
|--------|-------------------------------|----|
| 48-722 | Building Performance Modeling | 12 |
|--------|-------------------------------|----|

Selective Courses 45 units

| | | |
|--------|---|------|
| 48-795 | LEED | 6 |
| 48-721 | Building Controls and Diagnostics | 12 |
| 48-723 | Performance of Advanced Building Systems | Var. |
| 48-729 | Sustainability, Health and Productivity to Accelerate a Quality Built Environment | 9-12 |
| 48-749 | Special Topics in Computational Design | 6 |
| 48-752 | Zero Energy Housing | 9 |

Minimum Units: 54.

Minor in Architectural Design Fabrication

Available to architecture majors only (minimum 63 units total)

The Minor in Architectural Design Fabrication is intended for those who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) program.

Required Courses 30 units

| | | |
|--------|---|----|
| 48-531 | Fabricating Customization: Prototype | 9 |
| 48-545 | Design Fabrication | 9 |
| 48-555 | Introduction to Architectural Robotics | 9 |
| 48-xxx | ASO Studio with digital fabrication focus | 18 |

Selective Courses 30 units

| | | |
|--------|--|-----|
| 48-470 | The Depth of Surface | 9 |
| 48-473 | Hand and Machine Joinery, New Directions | 9 |
| 48-xxx | Design Fabrication Independent Study | 3-9 |
| xx-xxx | Pre-approved design fabrication course | |

Minimum Units: 63.

Minor in Computational Design

Available to both architecture majors and non-architecture majors (minimum 54 units total)

The minor in Computational Design is intended for students who wish to engage with computation as a vehicle of generative, material, and spatial design exploration. It brings together courses from the School of Architecture and the College of Fine Arts to offer students hands-on experience, and a deep understanding, of computation as a resource in creative design practices. Students minoring in computational design will be eligible for advanced standing in the School of Architecture's Master of Science in Computational Design (MSCD) program. The minor offers students the possibility of exploring three areas of computational design: designing, making, and theory. Please refer to this document (https://static1.squarespace.com/static/54c2a5c7e4b043776a0b0036/t/5f4eb94ce17d4e73ccb371/1598994764926/cd_minor_20200829.pdf) for the latest information.

Required Courses 30 units

| | | |
|--------|--------------------------------------|---|
| 62-122 | Digital Media I | 6 |
| 62-123 | Digital Media II | 6 |
| 62-225 | Generative Modeling | 9 |
| 62-275 | Fundamentals of Computational Design | 9 |

Selective Courses 24 units

| | | |
|-----------|--|----|
| Designing | | |
| 48-568 | Advanced CAD, BIM, and 3D Visualization | 9 |
| 51-367 | Design Center: Computational Design Thinking | 9 |
| Making | | |
| 48-530 | Human-Machine Virtuosity | 12 |
| 48-545 | Design Fabrication | 9 |
| 48-555 | Introduction to Architectural Robotics | 9 |
| 54-399 | Decoding Media | 9 |
| 54-405 | Digital Narratives | 5 |
| Theory | | |
| 48-727 | Inquiry into Computational Design | |
| 48-749 | Special Topics in Computational Design | 6 |

Minimum Units: 54.

Art Minor

The Art minor allows undergraduate students outside of the School of Art to pursue a largely studio-based minor in addition to their primary degree. Students can narrowly focus their interest or explore a number of mediums.

To declare an Art minor, students should contact Keni Jefferson (kjefferson@cmu.edu), in the College of Fine Arts, room 300. A portfolio is not required.

FOUNDATION MEDIA STUDIOS (CHOOSE TWO) 20 UNITS 20 units

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-135 | Foundations: Sculpture II | 10 |
| 60-137 | Ceramics for Non-Majors | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 60-157 | Drawing for Non-Majors | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

INTERMEDIATE/ADVANCED MEDIA STUDIO ELECTIVES (CHOOSE THREE) 30 UNITS 30 units

| | | |
|--------|-------------------------------|----|
| 60-2xx | Intermediate Studio Electives | 10 |
| 60-4xx | Advanced ETB: Electives | 10 |
| 60-4xx | Advanced SIS: Electives | 10 |
| 60-4xx | Advanced DP3: Electives | 10 |
| 60-4xx | Advanced CP: Electives | 10 |

Critical Studies (choose one) 9 units

| | | |
|--------|-------------------------------------|---|
| 60-105 | Cultural History of the Visual Arts | 9 |
| 60-3xx | Critical Theory Elective | 9 |

Minimum units: 59

Media Design Minor – IDeATe

The minor in *Media Design* is offered by the School of Art as part of the Integrative Design, Arts and Technology (<http://coursecatalog.web.cmu.edu/schools-colleges/collegeoffinearts/collegeoffineartsminors/ideate.cmu.edu>) (IDeATe) network. IDeATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDeATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. For more information about the IDeATe network, please see Undergraduate Options (p. 21).

The IDeATe *Media Design* minor invites students on a wide-ranging exploration of the digital media landscape. This multifaceted program encourages a holistic engagement with media technologies and practices, offering an opportunity to embrace the full breadth of media arts disciplines within the IDeATe network. Students gain the skills to design experiences across various platforms, from mobile devices to performances and large-scale installations, while gaining an understanding of how technology and content relate in new media systems, and how meanings are made in these evolving forms.

The flexibility inherent in the *Media Design* minor allows students to create a learning pathway that mirrors their unique interests, integrating elements from the other IDeATe minors. This approach makes it an ideal option for students who wish to experience the broad tapestry of digital media arts or those yet to pinpoint their exact focus within this dynamic field. The *Media Design* minor therefore cultivates versatile media practitioners, ready to innovate within the diverse and rapidly evolving digital media arena.

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDEATe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area | 10 |
| 16-223 | IDEATe Portal: Creative Kinetic Systems | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-125 | IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 60-223 | IDEATe Portal: Introduction to Physical Computing | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
| 99-361 | IDEATe Portal | 9 |

IDEATe Media Design Courses - Minimum of 27 Units

| | | Units |
|-----------|---|-------|
| 05/18-540 | Rapid Prototyping of Computer Systems | 12 |
| 15-294 | Special Topic: Rapid Prototyping Technologies | 5 |
| 15-394 | Intermediate Rapid Prototyping | 5 |
| 16/54-375 | IDEATe: Robotics for Creative Practice | 10 |
| 24-672 | Special Topics in DIY Design and Fabrication | 12 |
| 51-236 | Information Design | 9 |
| 51-400 | Transition Design | 9 |
| 53-250 | Immersive Experience Pre-production Process | 9 |
| 53-312 | Guest Experience in Theme Park Design | 9 |
| 53-376 | 360 Story and Sound | 12 |
| 53-558 | Reality Computing Studio | 12 |
| 54-399 | Decoding Media | 9 |
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-428 | Advanced ETB: Drawing with Machines | 12 |
| 60-461 | Advanced ETB: Experimental Capture | 12 |
| 62-362 | IDEATe: Electronic Logics && Creative Practice | 12 |
| 62-478 | IDEATe: digiTOOL | 9 |
| 67-240 | Mobile Web Design & Development | 9 |
| 67-265 | Design Fundamentals: Shaping Interactions and Experiences | 9 |
| 67-338 | Information & Grid Design | 9 |
| 76-374 | Mediated Narrative | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |

Additional course options as available. Please refer to the IDEATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Media Design* minor courses toward requirements for other majors or minors.

Design Minor

Minor in Design is a great way for students to diversify their studies and incorporate design skills and thinking into their overall academic experiences. Students who are already School of Design majors are not eligible to earn a Design minor. The 54 required units must be unique to the Design minor. No courses may be double counted.

Requirements and Electives

For a design minor, students must complete 54 units: 27 units of required courses, plus 27 units of design electives.

Required Design Courses

Three required courses:

| | | |
|-----------|---|---|
| 51-262 | Design Center: CD Fundamentals: Design for Interactions for Communications (formerly CDF) | 9 |
| or 51-261 | Design Center: Communication & Digital Design Fundamentals | |
| 51-264 | Design Center: Product Design Fundamentals: Design for Interactions for Products (formerly IDF) | 9 |
| 51-173 | Design Center: Human Experience in Design | 9 |

Three Design Electives:

| | | |
|--------|-----------------|---|
| 51-xxx | Design Elective | 9 |
| 51-xxx | Design Elective | 9 |
| 51-xxx | Design Elective | 9 |

Applications

Students must submit transcripts, personal statements, and completed applications by the beginning of February, and submit portfolios or design projects by the beginning of March. They must also obtain permission to complete minors from their major advisors. The minor application form includes detailed requirements.

Admission depends mainly on a student's demonstration of design skills and aptitude. Students are notified of acceptance by the end of March.

If you are interested in applying for the Minor in Design, please contact Design Advisor, Melissa Cicozi (cicozi@cmu.edu). You can download the Design Project and Application at www.design.cmu.edu (<http://www.design.cmu.edu>), or paper applications are available at the School of Design office, MMCH 110.

Drama Minor

The Drama minor provides students with a well-rounded opportunity to obtain preliminary professional exposure to the theatre arts. Courses may involve acting, directing, playwriting, design, production technology and management, and dramatic literature courses. Students also become involved with Drama productions by signing up for Production for Non-Majors, which involves evening crew work on various Drama productions.

Admission Requirements

1. Students must apply to enter the program in the office of the Drama Academic Advisor.
2. The student must successfully pass one Drama course prior to being considered for minor status.

Required Courses 25 units

| | | |
|--------|---|---|
| 54-163 | Production for Non Majors (needs to be taken twice for a total of 12 units) | 6 |
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II | 6 |

Students must meet with the School of Drama Production Manager (PCA 224) for assignments related to Production for Non-Majors.

Elective Courses 30 units

The remainder of the minor is fulfilled with Drama courses of the student's choosing, with approval from the Drama Academic Advisor. For certain courses, students may need instructor permission to register.

SAMPLE: Selected Elective Courses not requiring instructor permission:

| | | |
|--------|--|---|
| 54-187 | Writing the Adaptation for Stage and Screen | 9 |
| 54-190 | Creating the Choreopoem | 9 |
| 54-191 | Acting for Non-Majors | 9 |
| 54-193 | Acting for Non-Majors: Improv | 9 |
| 54-196 | Harvesting Personal Narratives: A Writing Workshop | 9 |

SAMPLE: Selected Elective Courses requiring instructor permission:

| | | |
|--------|-----------------------------------|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-157 | Production Science | 6 |
| 54-169 | Studiocraft 1 | 13 |
| 54-171 | Basic Design 1 | 6 |

Additional Drama Courses are available by instructor agreement and may require an audition, interview, or portfolio review. Students should contact the Drama Academic Advisor, to inquire about permission for specific courses in which they are interested.

Minimum units required: 55

Music Minors

Minor in Music

This sequence is for candidates who are majors from any discipline in the university other than music who have some background in music and would like to know more about music.

Admission Requirements:

1. The student must apply online to enter the program by submitting the minor application that is available here (<https://www.cmu.edu/cfa/music/current-students/guidelines-forms/music-minor.html>) on the Current Students website.

Prerequisite Course 0-3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

| | | |
|--------|----------------------------|---|
| 57-294 | Beginning Piano Test | 0 |
| 57-329 | Beginning Piano for Minors | 3 |

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

| | | |
|--------|--|---|
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-173 | Survey of Western Music History | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |

Required Studio Courses (studio fee is charged) 24 units

| | | |
|--------|-----------------|---|
| 57-1xx | Elective Studio | 6 |
| 57-1xx | Elective Studio | 6 |
| 57-1xx | Elective Studio | 6 |
| 57-1xx | Elective Studio | 6 |

Elective Courses 18 units

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog. Performance electives are encouraged. (An audition is required for all School of Music performance ensembles.)

Minimum units required: 67

Minor in Music Technology

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music technology.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Technology. See School of Music (p. 298).

Admission Requirements

1. The student must apply online to enter the program by submitting the minor application that is available here (<https://www.cmu.edu/cfa/>)

music/current-students/guidelines-forms/music-minor.html) on the Current Students website.

Prerequisite Course 0-3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

| | | |
|--------|----------------------------|---|
| 57-294 | Beginning Piano Test | 0 |
| 57-329 | Beginning Piano for Minors | 3 |

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

| | | |
|--------|--|---|
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-173 | Survey of Western Music History | 9 |
| 57-181 | Solfege I | 3 |
| 57-188 | Repertoire and Listening for Musicians | 1 |

Sound Recording Courses 21 units

| | | |
|--------|-----------------------------|---|
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Music Technology/Sound Courses (choose at least three) 21 units

Choose at least three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the music technology minor advisor.

| | | |
|--------|---|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-421 | Exploded Ensemble | 6 |

Minimum units required: 67

Minor in Music Theory

This sequence is for candidates who are majors from any discipline in the university who have some background in music and would like to know more about music theory.

Note: Students in the School of Music have slightly different requirements for the Minor in Music Theory. See School of Music (p. 298).

Admission Requirements

1. The student must apply online to enter the program by submitting the minor application that is available here (<https://www.cmu.edu/cfa/music/current-students/guidelines-forms/music-minor.html>) on the Current Students website.

Prerequisite Course 0-3 units

Beginning Piano for Minors is required of students who do not pass a beginning piano proficiency test.

| | | |
|--------|----------------------------|---|
| 57-294 | Beginning Piano Test | 0 |
| 57-329 | Beginning Piano for Minors | 3 |

Required Music Courses 25 units

Basic Harmony I and/or Basic Solfege I are required of students who do not qualify for entrance into Harmony I and/or Solfege I, based on their

scores on the theory and solfege placement tests. These classes fulfill the harmony and solfege requirements.

| | | |
|--------|--|---|
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-173 | Survey of Western Music History | 9 |
| 57-181 | Solfege I | 3 |
| 57-188 | Repertoire and Listening for Musicians | 1 |

Required Theory Courses **21 units**

| | | |
|--------|--|---|
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-153 | Harmony II | 9 |
| 57-408 | Form and Analysis | 6 |

Upper Level Theory Course (choose one) **6 units**

See theory courses on the Music Support Courses Two-Year Rotation list. It is available here (<https://www.cmu.edu/cfa/music/current-students/music-support-courses-f231.pdf>) on the Current Student website. A graduate course may be taken with the permission of the instructor.

Elective Courses **18 units**

Elective courses are to be chosen from those courses listed for the School of Music in the current course catalog.

Minimum units required: 70

Sonic Arts Minor – IDeATe

Sonic Art is a creative expression that uses sound as its primary medium. Just as visual artists create landscapes, portraits, and narratives through light, color, and form, sonic artists craft transformative experiences through sound, noise, and music.

Students in the *Sonic Arts* minor explore the processes and products of digital sound design and music production. They receive basic training in key component areas: principles of computer music, sound synthesis, spatialization, and core practices in sound design. Combining this training with courses that bring together experts from many disciplines, they create experimental music and explore emerging applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

| | Units | |
|--------|--|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDeATe Portal Course - Minimum of 9 Units

| | Units | |
|--------|--|----|
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| | Other IDeATe Portal Course by permission only. Consult the IDeATe advisor. | |

IDeATe Sonic Arts Courses - Minimum of 27 Units

| | Units | |
|---------------|--|---|
| 15-322 | Introduction to Computer Music | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-267 | Conceptual Sound Design | 9 |
| 54-509 | Theatrical Sound System Design 2 | 9 |
| 57-337 | Sound Recording | 6 |
| 57-344/60-407 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music portfolio required for registration | 9 |
| 57-359 | Audiovisual Composition | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-458 | Business of Music | 6 |

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Sonic Arts* minor courses for other requirements.

CFA Dean's Office Minors

Minor in the History of Arts

This minor of six or more courses as designated below, offers students flexibility to engage in a broad survey in the arts or can be tailored to reflect a more specific area of interest. For College of Fine Arts students, all courses meeting the requirements of the Minor in the History of the Arts must be taken outside of their major School, with the exception of the School of Architecture. Interested students should contact Dan Barrett (d Barrett@andrew.cmu.edu) in the College of Fine Arts, Room 100.

Introductory Level Courses **27 units**

(choose at least three, CFA students pick 3 outside of major)

| | | |
|--------|----------------------------------|---|
| 48-240 | History of World Architecture, I | 9 |
| 48-241 | History of Modern Architecture | 9 |

| | | |
|--------|--|------|
| 54-239 | History of Architecture and Decor 1: Ancients to Gothic | Var. |
| 54-240 | History of Architecture and Decor 2: Renaissance to the 21st Century | Var. |
| 54-245 | Who Wore What: When, Where, and Why (instructor permission only) | Var. |
| 54-246 | Who Wore What: When, Where, Why II (instructor permission only) | Var. |
| 57-173 | Survey of Western Music History (coreq: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians (coreq of 57-173) | 1 |
| 60-105 | Cultural History of the Visual Arts (instructor permission only) | 9 |
| 60-106 | Critical Theory in Art II | 9 |

Intermediate/Advanced Level Courses 27 units

(choose at least three, CFA students pick 3 outside of major)*

| | | |
|---|---|-----|
| 48-348 | Architectural History of Mexico & Guatemala | 9 |
| 48-374 | History of Architecture in the Islamic World- A Primer (prereq: 48-240) | 9 |
| 48-440 | American Regions & Regionalism: An Architectural History of Place, Time, and Cul (prereq: 48-240) | 9 |
| 51-376 | Semantics & Aesthetics | 4.5 |
| 57-209 | The Beatles | 9 |
| 57-476 | How Music Works: An Affective History | 6 |
| 57-477 | Music of the Spirit | 6 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-480 | History of Black American Music | 6 |
| 57-485 | History of the Symphony | 9 |
| Art Critical Studies Electives: 60-352 to 60-398 (instructor permission only) | | 9 |
| 62-360/79-328 | Photographers and Photography Since World War II | 9 |
| 62-371/79-316 | Photography, The First 100 Years, 1839-1939 | 9 |
| 79-395 | The Arts in Pittsburgh | 9 |

Minimum units required for minor: 54

*Other courses not on this list may qualify as approved by CFA Dean's Office (College of Fine Arts, Room 100).

Photography Elective (1) minimum 10 units

Choose one (1) or more additional photography courses from the list below in consultation with the photo advisor; consult Jamie Gruzka for current offerings.

| | | |
|--------|---|----|
| 62-208 | Alternative Photography: Contemporary Antiquarian Printmaking | 5 |
| 62-214 | Photography and the Narrative of Place | 5 |
| 62-235 | Photographing America | 10 |
| 62-245 | Portrait Photography | 10 |
| 62-375 | Large Format Photography: The Antiquarian Avant-Garde | 10 |
| 62-471 | Photography/ Print Workshop | 10 |
| 62-479 | Photography: Picturing Identity | 10 |

Minor in Photography

The Photography Minor exposes students to the breadth of offerings from traditional photography (i.e. film exposure and silver printing) to digital shooting and output. The student will become familiar with photography's craft, its history and significant practitioners, and develop their own distinct engagement with the medium.

Students may apply for the Photography Minor after they have taken a beginning photography course. Students will be admitted to the minor based on their aptitude, appropriate level of photography skills, and space availability within the program. Once admitted, students will be assigned a faculty advisor who will help them determine a sequence of courses that best fits their needs and interests.

Application Requirements

The application process for the Photography Minor requires submission of: a completed application form signed by the home department advisor, a personal statement, and a portfolio of photographs. Contact the CFA Photography Administrator, Jamie Gruzka (gruzska@andrew.cmu.edu), MM B18, for further information and an application form. Applications are processed every semester.

Photography Required Courses (3) minimum 30 units

| | | |
|-----------|---------------------------------|----|
| 62/60-141 | Black and White Photography I * | 10 |
| 62/60-142 | Digital Photography I | 10 |
| 62/60-241 | Black and White Photography II | 10 |

Photo History Required Course (1) minimum 9 units

62-371 Photography, The First 100 Years, 1839-1939 * 9
or 62-360 Photographers and Photography Since World War II

**History, Theory, or Criticism of the Visual Arts
Elective (1) minimum 9 units**

Choose one (1) additional History, Theory or Criticism of the Arts course in consultation with the photo advisor. A second Photo History course (62-360 or 62-371) can be used for this requirement.

*or course approved by the photography advisor

Minimum units required for minor: 58

School of Architecture

Omar Khan
Location: CFA 201
www.soa.cmu.edu (<http://www.soa.cmu.edu>)

The SoA educates students in the discipline of architecture emphasizing the role of creativity in architectural design; understanding its historical, social and environmental context; critically engaging technology in its innovation; and ethically working for social progress and justice in the built environment. Our undergraduate and graduate degree programs prepare students for the challenges facing architecture and urbanism in the twenty-first century, namely global warming, artificial intelligence and social justice. We aim to produce discipline-defining designers and thinkers in diverse global contexts.

This world-class architecture education is enhanced by our position within one of the world's leading research and entrepreneurship institutions, and by the fundamental premise that architectural excellence demands both rigorous training in fundamentals and the development of unique specializations. Students may extend their core knowledge either through concentration in architecture subdisciplines like urban design, sustainable design or computational design, or through interdisciplinary interaction with CMU's other renowned programs in the sciences, humanities, business and engineering. Though every SoA student graduates with intensive architecture knowledge, no two graduates leave with the same education.

In the twenty-first century, few architecture problems are straightforward. Graduates of SoA excel in the roles architects have performed for centuries - and in new roles catalyzed by the depth and breadth of their education - to create and execute innovative solutions to a huge range of emerging global challenges.

Undergraduate Degree Programs

The SoA offers two baccalaureate degree programs: the 5-year, professional Bachelor of Architecture (B.Arch), and the 4-year Bachelor of Arts in Architecture (B.A.). Both programs begin with the same studio-based curriculum in the first year, but then begin to diverge in terms of opportunities and outcomes. The B.Arch requires 10 studios and an extensive set of required professional courses, while the B.A. requires a minimum of 4 studios and fewer technical courses, all of which can be spread out over the four years of the program, and thus allow students to explore different opportunities in their studies.

Undergraduate students are admitted to the SoA without a declared degree program. By the end of the second year, students must select either the B.A. or the B.Arch degree program. The student's academic advisors, faculty, and Head provide mentoring and information to guide the student in selecting their degree option.

Bachelor of Architecture Program (B.Arch)

The Bachelor of Architecture (B.Arch) is a 5-year, first professional degree program accredited by the National Architectural Accrediting Board (NAAB, www.naab.org/accreditation/information/ (<https://www.naab.org/accreditation/information/>)) with a carefully defined set of "Program Criteria" (PC) and "Student Performance Criteria" (SPC). The B.Arch is for students proposing to pursue a career as a licensed architect or related profession, and centers around a carefully structured set of professional and technical courses about building design and construction, alongside the social, cultural and professional contexts in which architects operate. Our students graduate with a professional degree that prepares them to excel in practice—but that also launches them into key specialties within and around the profession.

Due to the technical nature of the B.Arch program at CMU, it is STEM-eligible, meaning that in addition to one year of Optional Practical Training (OPT), an international student on an F-1 visa may apply for a 24-month STEM OPT extension following graduation.

Statement on NAAB-Accredited Degrees

In the United States, most registration boards require a degree from an accredited professional degree program as a prerequisite for licensure. The National Architectural Accrediting Board (NAAB), which is the sole agency authorized to accredit professional degree programs in architecture

offered by institutions with U.S. regional accreditation, recognizes three types of degrees: the Bachelor of Architecture, the Master of Architecture, and the Doctor of Architecture. A program may be granted an eight-year term, an eight-year term with conditions, or a two-year term of continuing accreditation, or a three-year term of initial accreditation, depending on the extent of its conformance with established education standards.

Doctor of Architecture and Master of Architecture degree programs may require a non-accredited undergraduate degree in architecture for admission. However, the non-accredited degree is not, by itself, recognized as an accredited degree.

The Carnegie Mellon University School of Architecture offers the following NAAB-accredited programs:

- Bachelor of Architecture (450 units)
- Master of Architecture (Pre-professional degree or equivalent + 180 units)

The next NAAB accreditation visit for the Bachelor of Architecture is scheduled for 2027. The first NAAB visit for continuation of accreditation for the Master of Architecture is scheduled for 2023.

The full 2020 NAAB Conditions for Accreditation can also be found on NAAB's website at: www.naab.org/accreditation/conditions-and-procedures/ (<https://www.naab.org/accreditation/conditions-and-procedures/>).

Bachelor of Arts in Architecture Program (B.A.)

The Bachelor of Arts in Architecture (B.A.) is a 4-year liberal studies degree program that allows and encourages interdisciplinary exploration. The program is built around a core foundation of architectural studios and technical coursework, but more than half of the units required for graduation are general studies courses and flexible electives. B.A. students have the opportunity to double major, test the boundaries of the discipline, and explore a variety of interests. If you are a student that embraces creativity, is curious about the world around you, and enjoys engaging both the left and right sides of your brain, the B.A. program could be a perfect fit for you.

As a 4-year, pre-professional architecture program, the B.A. allows those who are interested to continue in architecture with a 2-year professional M.Arch degree program (often called a 4+2 degree), or to go on to specialize in other fields in graduate school, including urban design, landscape architecture or other fields related to design, the built environment, virtual worlds, community engagement, sustainability, and more. The B.A. also makes it possible for students to transfer into architecture from other studies.

In the first year, the B.A. program begins with the same studio-based curriculum as the B.Arch program, but then begins to diverge in terms of opportunities and outcomes. The B.A. requires only the first four studios and the core courses from the first two years of the B.Arch sequence, and these can be spread out over the four years of the program. Students may take more studios, specialize in particular aspects of architecture, or explore broadly.

For students seeking to integrate architecture with another field of study, CMU also offers the BXA Intercollege Degree Programs. BXA students graduate with a Bachelor of Humanities and Arts, a Bachelor of Science and Arts, or a Bachelor of Computer Science and Arts degree.

B.Arch Curriculum

Minimum units required for Bachelor of Architecture 450

First Year: Poesis

| | | |
|--------|--|----|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 | 15 |
| 48-104 | Shop Skills | 3 |
| 62-122 | Digital Media I | 6 |
| 62-104 | Design Ethics & Social Justice in Architecture | 3 |
| 62-125 | Drawing I | 6 |

| | | |
|-----------------------------|---|----|
| 76-101 | Interpretation and Argument | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 48-105 | Architecture Design Studio: Poiesis Studio 2 | 15 |
| 62-123 | Digital Media II | 6 |
| 62-126 | Drawing II | 6 |
| 48-240 | History of World Architecture, I | 9 |
| 48-xxx | Pittsburgh | 3 |
| xx-xxx | Elective | 6 |
| Second Year: Poiesis | | |
| 48-200 | Architecture Design Studio: POIESIS STUDIO 3 | 18 |
| 48-215 | Materials & Assembly | 9 |
| 48-116 | Introduction to Building Performance | 3 |
| 62-225 | Generative Modeling | 9 |
| xx-xxx | Elective | 6 |
| 48-205 | Architecture Options Studios | 18 |
| 48-241 | History of Modern Architecture | 9 |
| 48-234 | Introduction to Structures | 3 |
| 62-275 | Fundamentals of Computational Design | 9 |
| 48-xxx | Seminar II | 3 |
| xx-xxx | Elective | 6 |
| Third Year: Praxis | | |
| 48-300 | Architecture Design Studio: Praxis Studio 1 | 18 |
| 48-315 | Environment I: Climate & Energy in Architecture | 9 |
| 48-250 | Urbanism and the Social Production of Space | 9 |
| 48-xxx | Architectural History III (Selective) | 9 |
| xx-xxx | Elective | 6 |
| 48-305 | Architecture Design Studio: Praxis Studio 2 | 18 |
| 48-380 | Real Estate for Architects | 6 |
| 48-xxx | Building Physics 2 | 6 |
| 48-xxx | Structures 2 | 6 |
| xx-xxx | Elective | 9 |
| Fourth Year | | |
| 48-400 | Architecture Design Studio: Praxis Studio 3 | 18 |
| 48-432 | Environment II: Design Integration of Active Building Systems | 9 |
| xx-xxx | Design Ethics (Selective) | 3 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 6 |
| 48-405 | Advanced Synthesis Options Studio II | 18 |
| 48-381 | Issues of Practice | 6 |
| 48-383 | Ethics and Decision Making in Architecture | 6 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 3 |
| Fifth Year | | |
| 48-500 | Advanced Synthesis Options Studio | 18 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 6 |
| 48-510 | Advanced Synthesis Options Studio IV | 18 |
| or 48-519 | Architecture Design Studio: Thesis II/ Independent Project | |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 9 |
| xx-xxx | Elective | 6 |

B.A. Curriculum

Minimum units required for Bachelor of Arts in Architecture 360

Design Studios

| | | |
|--------|--|----|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 | 15 |
| 48-105 | Architecture Design Studio: Poiesis Studio 2 | 15 |

| | | |
|--------|--|----|
| 48-200 | Architecture Design Studio: POIESIS STUDIO 3 | 18 |
| 48-205 | Architecture Options Studios | 18 |

Architecture Coursework

| | | |
|--------|---|---|
| 48-104 | Shop Skills | 3 |
| 48-xxx | Pittsburgh | 3 |
| 48-240 | History of World Architecture, I | 9 |
| 48-241 | History of Modern Architecture | 9 |
| 48-116 | Introduction to Building Performance | 3 |
| 48-250 | Urbanism and the Social Production of Space | 6 |
| 48-215 | Materials & Assembly | 9 |

General Studies

| | | |
|--------|--|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 48-025 | First Year Seminar: Architecture Edition I | 3 |
| 76-101 | Interpretation and Argument | 9 |
| 48-xxx | Seminar II | 3 |
| 62-104 | Design Ethics & Social Justice in Architecture | 3 |
| 62-122 | Digital Media I | 6 |
| 62-123 | Digital Media II | 6 |
| 62-125 | Drawing I | 6 |
| 62-126 | Drawing II | 6 |
| 62-225 | Generative Modeling | 9 |
| 62-275 | Fundamentals of Computational Design | 9 |

Electives

| | | |
|--------|------------------------------------|-----|
| 48-xxx | Architecture Electives | 45 |
| xx-xxx | University Electives (Outside SoA) | 45 |
| xx-xxx | Flex Electives (In or out of SoA) | 105 |

Minors in Architecture

The SoA offers several minors in various specialty subjects related to architecture, some are only available to non-architecture students, others are only available to architecture majors, and still others can be taken by all CMU students. For the most up-to-date list of minors, see: <https://soa.cmu.edu/minors> (<https://soa.cmu.edu/minors/>).

Non-architecture students may minor in: Architecture, Architectural History, Architectural Representation & Visualization, Architectural Technology, and Computational Design.

Architecture majors may minor in: Architectural Design Fabrication, Architectural History, Architectural Representation & Visualization, Building Science, and Computational Design.

The **Minor in Architecture** sequence is for students who intend to develop intellectual links to the architectural profession. The scope of courses offered includes a full spectrum of professional issues in architecture. (*Available to non-architecture majors only.*)

The **Minor in Architectural Design Fabrication** is intended for students who wish to develop focused, disciplinary expertise in both analog and digital material methods for shaping the built environment and become involved in a community of practice dedicated to a rigorous pursuit of *making* as a mode of architectural research and cultural expression. It is also for students interested in gaining advanced placement in the SoA's Master of Advanced Architectural Design (MAAD) (<https://soa.cmu.edu/maad/>) program. (*Available to architecture majors only.*)

The **Minor in Architectural History** is intended for candidates interested in the history of architecture in its many manifestations, including high style and vernacular buildings, western and non-western traditions, built and theoretical works, and rural to urban contexts. Students wishing to pursue the minor should meet with the Architecture advisor to determine if a course is eligible. (*Available to both architecture majors and non-architecture majors.*)

The **Minor in Architectural Representation and Visualization** is intended for students who wish to develop particular skills in architectural representation, and for those who are interested in gaining advanced placement in the SoA's Master degree program in Computational Design (MSCD) (<https://soa.cmu.edu/mscd/>). (*Available to both architecture majors and non-architecture majors.*)

The **Minor in Architectural Technology** is intended for students who seek to develop intellectual links to the technical aspects of the profession. (*Available to non-architecture majors only.*)

The **Minor in Building Science** is intended for students that want to deepen their knowledge in the building sciences, and for those who are

interested in gaining advanced placement in the SoA's Master degree programs in Building Performance & Diagnostics (MSBPD) (<https://soa.cmu.edu/bpd/>) or Sustainable Design (MSSD) (<https://soa.cmu.edu/mssd/>). (Available to architecture majors only.)

The **Minor in Computational Design** is intended for students who wish to engage with computation as a vehicle of generative, material, and spatial design exploration, and for those who are interested in gaining advanced placement in the SoA's Master of Science in Computational Design (MSCD) (<https://soa.cmu.edu/mscd/>). (Available to both architecture majors and non-architecture majors.)

Advanced Standing in Master Degree Programs

The SoA offers a unique opportunity to undergraduate students who wish to pursue a post-professional Master's degree in an architecture-related field. The Accelerated Master's Program (AMP) (<https://soa.cmu.edu/accelerated/>) offers baccalaureate students the opportunity to expedite their completion of a Master's degree, saving both time and money—and allowing them to hit the job market with specialized knowledge and two CMU degrees. Baccalaureate students can pursue a graduate degree in the following subjects: Master of Architecture (M.Arch) (B.A. students only), Advanced Architectural Design, Architecture-Engineering-Construction Management, Building Performance and Diagnostics, Computational Design, Sustainable Design, and Urban Design. An AMP student must complete all of the units required by BOTH programs, less a maximum of 48 units that can be double-counted. For instance, B.Arch + MSSD-Applied would be 450 units + 135 units less 48 double-counted units, or 537 total units total for two degrees. B.Arch students may begin pursuit of a post-professional Master's degree through AMP as early as their third year.

Graduate Degree Programs

Carnegie Mellon University is recognized for outstanding contributions to science, technology, management, policy, and the fine arts. The School of Architecture builds on a tradition of interdisciplinary study. **The School of Architecture offers seven (7) Master's degrees, and three (3) Doctoral degrees in the following areas of study:**

Master of Advanced Architectural Design

The Master of Advanced Architectural Design (MAAD) (<https://soa.cmu.edu/maad/>) is a post-graduate, studio-based program that engages emerging methods of design and fabrication through architectural design to speculate upon future modes of architectural practice, enhanced construction methods, and material culture within the built environment.

Master of Architecture

The Master of Architecture (M. Arch) (<https://soa.cmu.edu/march/>) is two-year, studio-based, NAAB-accredited (<https://soa.cmu.edu/about/#naab>), first professional degree program to educate tomorrow's leaders in architecture-related careers. It requires a 4-year, pre-professional architecture program such as the B.A. or its equivalent to enroll, and is thus often called a 4+2 degree. The M.Arch program provides both the broad, comprehensive training in fundamentals required for U.S. professional registration and licensure, and the opportunity to focus on, speculate in, and obtain dual degrees with other research-based master's programs in the SoA. Our M.Arch program's strategically small size allows our self-motivated students to shape their individual educational agendas and career paths as they interact directly with a broad array of vertically integrated studios and advanced research projects in the school, the university, the local community, and around the world.

Master of Science/Doctor of Philosophy in Architecture-Engineering-Construction Management

A joint effort between the School of Architecture and the Department of Civil & Environmental Engineering, the Architecture-Engineering-Construction Management (AECM) (<https://soa.cmu.edu/aecm/>) programs prepare building delivery professionals for careers in capital project delivery dealing with the entire life-cycle of capital projects, from pre-design to design, construction, commissioning, operation, and maintenance stages. Graduates are educated to become effective decision makers who can positively impact economic, environmental, and ethical aspects of the built environment through professional management strategies. Our graduates have successful careers in government, industry, business, and NGO (non-governmental organization) sectors, prospering in positions where design professionals continuously make large-scale capital project design, construction, and maintenance decisions.

Master of Science/Doctor of Philosophy in Building Performance and Diagnostics

Our graduate programs in Building Performance & Diagnostics (BPD) (<https://soa.cmu.edu/bpd/>) have long led the world in advanced building technologies that sustainably reshape the built environment. BPD deals with the comprehensive integration of *building design* and *advanced technology*, as a means of producing high performance architecture. Led by the Center for Building Performance & Diagnostics (CBPD) (<https://soa.cmu.edu/cbpd/>) and housed within the Robert L. Preger Intelligent Workplace (<http://www.cmu.edu/greenpractices/greenign-the-campus/green-buildings/intelligent-workplace.html>), students have the opportunity to gain both diversity and depth of knowledge from world-renowned and experienced faculty.

Master of Science/Doctor of Philosophy in Computational Design

Our graduate programs in Computational Design (<https://soa.cmu.edu/computational-design/>) are among the first and best known in the country, and our legacy continues today. The Computational Design program takes a computer science view of design, applying both the science and art of computing to design problems, in relation to creation, presentation, analysis, evaluation, interaction or aesthetic expression; in real and imagined applications, both perceived and conceived. From the beginning, the program has benefitted from close cooperation with other units of the university, particularly the School of Computer Science and the Department of Civil & Environmental Engineering. Our research-based degree programs are intended for practitioners, educators and researchers in architecture, computer science, engineering and those interested in design. Our graduates go on to successful careers in government, industry, academia, and software development.

Master of Urban Design

The Master of Urban Design (MUD) (<https://soa.cmu.edu/mud/>) is a studio-based program distinguished by its emphasis on integrating socially engaged practice with new tools and techniques for representing, understanding, and designing cities; by the opportunity to work in trans-disciplinary teams at the intersection of the arts, humanities and technology across Carnegie Mellon's departments and colleges; and by its location in Pittsburgh—a thriving post-industrial laboratory.

MASTER OF SCIENCE IN SUSTAINABLE DESIGN

The Master of Science in Sustainable Design (MSSD) (<https://soa.cmu.edu/mssd/>) is a post-professional research-based graduate program focused on enabling deep expertise, critical thinking, and investigation of innovative sustainable strategies for the design of the built environment. The MSSD program explores technical and multicultural aspects of ecological thinking, while enabling actionable expertise in sustainable design methodologies. Based in the legacy of sustainability teaching at Carnegie Mellon University, the MSSD program prepares students to excel in research methods, and to become experts in integrative design thinking for the future of the built environment.

Student Advising

Architecture students can receive advice from many sources, including the faculty, staff, and administration of the School. All SoA undergraduates are urged to meet with the Senior Academic Advisor to review their academic progress and plans before each semester. Such meetings are important to take full advantage of elective possibilities within the curriculum, general progress toward graduation, and professional goal-setting. Students may also check their progress using the online academic audit in the Student Information Online (SIO) and should review the audit results with the senior academic advisor. The Academic Advisor will assist students with registration, academic audits, transfer credits, study abroad, SoA minors, finals grades and academic actions, as well as SoA and university policies and resources.

In addition, we encourage all of our students to become involved with student organizations such as AIAS or NOMAS, as well as committees such as the Student Advisory Council (SAC) in order to learn from peers. Students should seek advice about the Architectural Experience Program (AXP) and architectural licensing through the Architect Licensing Advisor

Study Abroad

The SoA strongly encourages students to study abroad. The perspective gained through immersion in another culture and language is invaluable. A student is exposed to architectural subjects not readily available at CMU and will study architecture directly in a foreign context. The Office of

International Education (OIE) is an excellent resource for getting started for study abroad planning.

Study abroad can fall into four categories: University Direct Exchanges, University Sponsored Programs, External Programs, and Departmental Summer Programs.

Students are allowed one semester abroad for which they receive studio credit except for those students at approved direct, year-long exchange programs. Students may study abroad in the Fall, Spring, or Summer semesters. Careful planning and scheduling of your courses are necessary when incorporating a study away experience into your curriculum. Students should investigate and start making decisions to study abroad by the fall of their second year, so they can plan their courses accordingly. Please see the academic advisor prior to making any decisions on what term to schedule your study away experience.

To qualify for a study abroad program other than the departmental summer programs, a student must have completed their third year of the program, have a minimum overall QPA of 3.00, and be in good academic standing (no current academic actions).

Students in SoA departmental summer programs must have completed their first year, and must be free of any academic actions for the semester prior to studying away, or permission may be denied. Students can petition the UPEC for exceptions.

Students who participate in a study abroad program for one semester will transfer non-studio course credit by submitting course descriptions of each course taken as well as an official transcript from the host Institution. Official translated transcripts must be submitted to the academic advisor before the beginning of the academic year to receive transfer credit. Grades are not transferred, only credits. Transfer credit is awarded upon receipt of an official translated transcript and only for courses with the grade of a C or better (not C-). When students return from study abroad, they must pin up original work during the study away exhibit, which will be subject to review by the UPEC or designated faculty.

Faculty

JARED ABRAHAM, Associate Studio Professor

VICKY ACHNANI, Adjunct Instructor

SAROSH ANKLESARIA, Fitz-Gibbon Visiting Professor

MARY-LOU ARSCOTT, Studio Professor & Associate Head

NINA BAIRD, Assistant Teaching Professor

NINA BARBUTO, Adjunct Faculty

JOSHUA BARD, Associate Professor & Associate Head

WILLIAM BATES, Adjunct Faculty

ARDAVAN BIDGOLI, Robotics Fellow

PRIYANKA BISTA, Joseph F. Thomas Visiting Professor

HEATHER BIZON, Special Faculty

GINGER BROOKS TAKAHASHI, Adjunct Instructor

DARAGH BYRNE, Associate Teaching Track

DANIEL CARDOSO LLACH, Associate Professor

DONALD CARTER, Adjunct Faculty

MARK CHAMBERS, Adjunct Instructor

JEFFIE CHANG, Adjunct Instructor

ANNE CHEN, Adjunct Instructor

XIN CHEN, Adjunct Instructor

NICKIE CHEUNG, Adjunct Instructor

ERICA COCHRAN HAMEEN, Assistant Professor & Director of DEI

DOUG COOPER, Andrew Mellon Professor

STUART COPPEDGE, Adjunct Instructor

DANA CUPKOVA, Associate Professor

GERARD DAMIANI, Associate Professor

STEFANI DANES, Adjunct Faculty

JEFFREY DAVIS, Adjunct Faculty

TAMARA DUDUKOVICH, Adjunct Instructor

EMEK ERDOLU, Graduate Instructor

JEREMY FICCA, Associate Professor, Director dFAB

LAURA GARAFALO, Associate Professor

SINAN GORAL, Adjunct Faculty

STEFAN GRUBER, Associate Professor

KAI GUTSCHOW, Associate Professor & Associate Head

NAJEEB HAMEEN, Adjunct Faculty

VOLKER HARTKOPF, Professor Emeritus

HAL HAYES, Studio Professor

MATTHEW HUBER, Adjunct Faculty

ELIJAH HUGHES, Adjunct Instructor

THEODOSSIS ISSAIAS, Special Faculty

JENNA KAPPELT, Special Faculty

LYNN KAWARATANI, Liason Librarian to SoA

OMAR KHAN, Professor & Head

PHYLLIS KIM, Adjunct Instructor

JONATHAN KLINE, Associate Studio Professor

KRISTEN KURLAND, Teaching Professor

JONGWAN KWON, Special Faculty

KHEE POH LAM, Professor Emeritus

JOSHUA D. LEE, Assistant Professor

JUNEY LEE, Assistant Professor

STEPHEN R. LEE, Professor

SUZI LI, Graduate Instructor

TIAN LI, Graduate Instructor

WEI LIANG, Graduate Instructor

VIVIAN LOFTNESS, University Professor, Paul Mellon Professor

TONYA MARKIEWICZ, Adjunct Instructor

JACKIE JOSEPH PAUL MCFARLAND, Special Faculty

CHRISTINE MONDOR, Special Faculty

MELANIE NGAMI, Adjunct Instructor

NILOOFAR NIKOOKAR, Graduate Instructor

VERNELLE NOEL, Assistant Professor

PAUL OSTERGAARD, Adjunct Faculty

PAUL PANGARO, Visiting Scholar in Computational Design

MISRI PATEL, Anne Kalla Visiting Professor

NIHAR PATHAK, Graduate Instructor

STEPHEN QUICK, Adjunct Faculty

SARAH RAFSON, Adjunct Faculty

NIDA REHMAN, Lucian and Rita Caste Assistant Professor in Architecture and Urban Design

MANUEL RODRÍGUEZ LADRÓN DE GUEVARA, Studio Instructor & Research Assistant

AZADEH OMIDFAR SAWYER, Assistant Professor

NATHAN SAWYER, Special Faculty

CHARLIE SCHMIDT, Adjunct Instructor

EDWARD SEGAL, Adjunct Instructor

DIANE SHAW, Associate Professor

TULIZA SINDI, Anne Kalla Visiting Professor

ALA TANNIR, Adjunct Instructor

FRANCESCA TORELLO, Special Faculty

KUSHAGRA VARMA, Graduate Instructor

VALENTINA VAVASIS, Special Faculty

GERROD WINSTON, Adjunct Instructor

GARRET WOOD-STERNBURGH, Adjunct Instructor

HEATHER WORKINGER MIDGLEY, Adjunct Faculty

TOMMY CHEEMOU YANG, Anne Kalla Professor in Architecture

TIANCHENG ZHAO, Graduate Instructor

School of Architecture Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

48-025 First Year Seminar: Architecture Edition I

Fall: 3 units

The main objective of this first-year seminar course is on how students learn, develop, and make decisions as they transition into architecture education. The goal of this course is to promote academic success and encourage connections within the SoA and the University at large. Teaching and learning strategies will be introduced to help support the transition into architecture and the development of independent critical thinkers. Students will be introduced to campus resources that support their academic/social/personal integration into the campus community. Topical areas to be covered in the seminar will include academic success strategies in architecture education, academic development, career planning, mentorships, academic and personal support services, and the aspects of professional practice in architecture.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-026 First Year Seminar: Architecture Edition II

Spring: 3 units

The first-year seminar (part 2) introduces students to opportunities at Carnegie Mellon University and beyond. The goal of this course is to encourage students to pursue their interests inside and outside of the School of Architecture by introducing a range of opportunities, including study abroad experiences, internships, academic minors/additional majors, and research opportunities. Additional topical areas to be covered in the seminar will include an evaluation of the previous semester, scholarship/academic funding opportunities, ethical decision making, design resume writing/branding, and engaging with the Career and Professional Development Center.

Course Website: <http://soa.cmu.edu>

48-095 Spatial Concepts for Non-Architecture Majors

Fall and Spring: 10 units

This course serves as an introduction to the spatial concepts of architecture for students from other disciplines. The course is focused entirely on project design work (this is not an historical survey, technical or lecture course). This course is very hands-on. Projects will explore the design and experience of spatial environments through a series of creative investigations. The semester will be broken in to 3 parts: Intro/Exploration and a long term project. In Intro/Exploration, students will have many hands on opportunities to start to build a common language to describe spacial investigations as well as creating them. This will consist of short projects, with each design investigation progressively building upon the previous exploration; these early projects will consist of both individual and group work. They will focus on Making. The second half of the semester will consist of one long term project to be created individually, incorporating students' personal theories of architecture based on an overarching question. Studio work will be supported by group discussion based upon critical review of student work, readings, slide presentations, videos and films. There will also be a few field trips. Students are encouraged to explore their own areas of interest with respect to their work in class. Self-motivation, class attendance and an open mind is mandatory, however, no prior architectural, engineering or artistic experience is required. Students are expected to perform work both inside and outside of class. Students should be prepared to purchase various supplies throughout the course. This course is in partial fulfillment of requirements for an Architecture Minor.

48-100 Architecture Design Studio: POIESIS STUDIO 1

Fall: 15 units

This studio will investigate the role and process of architectural design as different forms of practice. The studio will practice drawing, making, and building architectural narratives in iterations at various scales of time and space, to establish productive habits and develop essential techniques and skills in architectural design. In learning how architects see in both visible and invisible terms, the studio will analyze design precedents and problems that generate ideas about architectural material, form, and systems. In understanding how architects empathize with whom or what they serve, the studio will rigorously investigate methods of abstraction and critical dimensions relative to human form and experience. In practicing how architects deliver in the professional context, the studio will develop mastery of spatial composition, representation, and narrative as means for an architect to iteratively test, experiment with, and communicate spatial ideas.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-104 Shop Skills

Fall

This course will introduce basic material assembly methods, and the use of shop machinery, hand and power tools. It prepares students to participate in a wide range of subsequent building and fabrication projects. We will aim to build confidence and safe work habits while demystifying the interactions between tools and physical materials.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-105 Architecture Design Studio: Poiesis Studio 2

Spring: 15 units

As the second studio within the Poiesis Sequence, this studio will nurture a way of making and thinking in design that aims to cultivate the practice of architecture as an act of creative citizenship. By building an affinity for an approach linking the cross-cultural study of how people perceive and manipulate their environments can push a multimodal understanding of architecture and urban design. We will use a multi-disciplinary approach to become detectives interrogating the contemporary and historical tissue of Pittsburgh through the occupations and working lives, therefore elevating ordinary folks and trades that had and continues to foster the fabric of the city. Grasping the multi-faceted changing environment, this studio will use architectural tools as a base of inquiry to speculate and allow us to transform the way we view our world through multiscale multisystemic perspectives. The structure of the studio will follow one cohesive research driven design project that will explore narrative modalities, by using critical cartography, archival research, storytelling, programming adjacencies and tectonic exploration as a method to produce a hybrid shop-house focused on the historical trades of Pittsburgh. Students in the sequence will be introduced to critical proficiencies, learn new techniques of representation, adapt rigorous illustration and animation tools in the production of a dwelling project that is rooted in its urban fabric.

Prerequisite: 48-100 Min. grade C

48-116 Introduction to Building Performance

All Semesters: 3 units

This course will introduce fundamental concepts of building physics. The knowledge and skills obtained from this course can be applied to studio projects and beyond, improving building design and performance through standard methods of evaluation and simulation tools. Course curriculum running concurrent with studio projects will aid students in further developing and guiding design decisions to incorporate fundamental concepts related to climate, energy, light, relationship to site, and occupant visual and thermal comfort. Students will develop a general understanding of, site analysis, building placement and amp; form as it relates to building performance, photometric principles to evaluate lighting conditions, thermodynamic principles, and heat transfer, building energy, renewable and embodied energy. Skills, tools, and knowledge base learned in this course with enable designers and architects to employ sustainable practices at all phases of design, leading to better performing buildings.

Prerequisites: 62-122 and 62-123 and 62-125 and 62-126

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-120 Digital Media I

Fall: 6 units

IDM is a required course for all first year architecture students. The course introduces students to a wide range of digital methods and concepts available to architects for design, representation, and documentation. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM addresses topics such as digital image editing, vector illustration, HTML coding, and 3D modeling.

48-121 Drawing I

Fall: 6 units

Architects draw and build models for a variety of reasons: to record and reference; to analyze and reveal order, intent, and relationships; to speculate; and to visualize new propositions. The study of architecture requires the connection between the mind, the eye and the hand, so that the nature of ideas and their relationship to physical form can be investigated. The connection of the mind, hand and drawing skills requires considerable time and effort. This course introduces why architects use these forms of representation. Students are introduced to how to do basic academic research as well direct assignments that apply the fundamentals of freehand drawings and drafting techniques as it pertains to plans, sections, elevations and paraline drawing, analytical diagraming and model making.

48-125 Digital Media II

Spring: 6 units

IDM2 is a required course for all first year architecture students. This course is the continuation of IDM. IDM2 introduces students to measured drafting and the process of creating a construction drawing set. The coursework is directly coordinated with Studio assignments providing the students with the opportunity to master their digital skills in a meaningful manner. Due to the amount of content covered there is no single text for this course, but the course is supported by materials created by the instructor. IDM2 addresses topics such as digital drafting, construction drawings, advanced 3D modeling and HTML programming.

Prerequisite: 48-120

48-126 Drawing II

Spring: 6 units

Drawing and Appearance? is a traditional course in free-hand architectural drawing. Its central learning objective is building a capacity for visualizing three-dimensional space through the making of hand-made drawings. Two secondary objectives foster visual literacy: the ability to use line, tonal values and color to represent architectural space and the ability to use drawing to represent architectural proposals at various levels of abstraction. Coursework includes free-hand and constructed perspective, shade and shadow projection, chiaroscuro drawing in colored pencil and color drawing in pastel. Work is submitted in three portfolio submissions of two weeks duration each. Coursework is built around exercises in the required course text: Drawing and Perceiving, John Wiley and Sons.

48-175 Descriptive Geometry

Spring: 9 units

Descriptive geometry deals with solving problems in three-dimensional geometry through working with two-dimensional planes using basic mechanical tools. Descriptive geometry deals with physical space, the kind that one is used to since birth. Things one can see around us have geometry and even things that one cannot see, also have geometry. All these things concern geometric objects almost always in relationships that is, next to, above, below, intersecting with, occluding, hidden by and so onto one another that sometimes requires us to make sense of it all in other words, when we try to solve geometric problems albeit in architecture, engineering, or the sciences. In fact, descriptive geometry has proved itself to be practically useful; it has been one of the more important factors in the design of scientific apparatus, engineering systems and architectural structures. It is the basis of modern geometrical computing. Descriptive geometry is constructively meaningful, one uses conventional mechanical drawing tools: namely, compass, ruler, protractor, divider, triangles, etc., to construct solutions to geometric problems. This course specifically revolves around the historical techniques for manually solving three-dimensional geometry problems.

Course Website: <http://soa.cmu.edu>**48-200 Architecture Design Studio: POIESIS STUDIO 3**

Fall: 18 units

The Poiesis Studio 3 explores how architectural and landscape design can respond to a local biome. With a focus on climate and ecology, it highlights the use of precedent and the relevance of context in how architecture takes shape - how it develops its morphology. As the architectural profession collectively recognizes the built/natural environment as a complex web of interacting parts constantly exchanging energy and resources, we become interested in developing architecture that contributes to context from which it arises. In response Poiesis 3 will seek to support and enrich the local ecology (both cultural and natural) in a similar way to how a biome's flora and fauna both adapt to their surroundings and help form sustaining ecosystems. The studio gives students a foundation in site and precedent analysis, passive design strategies, and ecological and environmental systems thinking. Through an iterative process you will develop formal and programmatic organizations as field conditions, or aggregations that highlighting the localized interconnectivity of buildings, bodies, and environment and redefine boundary conditions. Merging architecture and landscape, your resulting morphologies will become a mediator between interior and exterior, public and private, the social and the ecological. Working from the scale of the site to that of the envelope your designs will arrive at a sensorially rich, environmentally responsive and resilient architecture.

Prerequisites: 62-123 and 48-025 and 62-104 and 62-126 and 62-125 and 62-122 and 48-105 Min. grade C and 48-100

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-205 Architecture Options Studios**

Spring: 18 units

This studio aims to entirely reimagine the Mobile Home; to challenge its cultural stigma, and to propose new and innovative thinking on home design, home delivery, mobility, community, and the ever-evolving definition of the American Dream. During the post-war period, "Motor Coaches" were seen as an ideal solution to a growing housing shortage. Early Mobile Home design presented an opportunity to develop new housing typologies viewed as cutting-edge and innovative; marketed as both a "modern" and affordable means of living. Since the post-war period, Mobile Homes and their occupants have been relegated to the periphery of American society. Housing stock is aging, and new homes have failed to adapt to contemporary modes of living. The Mobile Home presents an affordable housing typology that is widely ignored by Architects despite a growing demand for small, affordable and efficient housing. The first half of the semester will focus on the design of a new Mobile Housing Prototype. During the second half of the semester, students will refine their prototypes while adopting a specific region of the US in which to adapt their designs. Throughout multiple cycles of research and design, we will use physical models and orthographic drawings as our primary means of investigation and representation. Consideration will be given to culture, image, form, typology, economy, prefabrication, deconstruction, aesthetics, and experience.

Prerequisite: 48-200

Course Website: <http://soa.cmu.edu>**48-215 Materials & Assembly**

Spring: 9 units

This course introduces and examines the fundamentals between design intent and construction materials, and the science of materials (performance) and their assemblies. Learning how materials and techniques inform spatial and form making decisions will be a central theme for the semester. Lectures and discussions will focus on the meaning, aesthetics and techniques related to the use of materials and the process of construction. A basic understanding of essential, well-known systems of building construction will be our base line. Discussions and case studies of contemporary systems that extend, experiment with and question these known systems will introduce you to the great depth to which this basic knowledge can lead you. Joint assignments with the design studio will provide you with an opportunity for an in-depth exploration of these fundamentals of construction through a direct application and synthesis of this new knowledge to your studio project.

Prerequisite: 48-100

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-217 Structures**

Spring: 9 units

Structures is a required course taught in the second year. It is a successor course to Statics, complementing that previous course by emphasizing structural member design in wood, steel, and reinforced concrete; spatial synthesis of hierarchical one-way systems for gravity load; structural types for lateral load including braced frames, shear walls, and rigid frames; introduction to geometric structures such as cable nets, domes, shells, and air-supported structures.

48-222 Explorations in Craft: Soft Forms, Stable Structures

Fall and Spring: 9 units

This course focuses on physical model making of soft forms. Softness is an evocative quality in architecture, but how do we "find" and then represent those elusive soft forms? How do we demonstrate a level of intentionality and control in their execution outside the digital realm? How do we suspend disbelief and open haptic possibilities? How do we manipulate materials with control? Using soft materials and/or expressing fluid form we will explore analog and digital craft pairings for fabrication, assembly methods, and physical form-finding techniques. The design and use of items like cutting and sewing patterns, bending jigs and casting molds will introduce the types of interfaces that facilitate thoughtful crafting of models. While learning through making, students will develop their own expression of softness. Presentations, demonstrations, and workshops on craft will inform experiments focused on material qualities and their formal affordances. Explorations and experiments will also consider structural stability in relation to soft material and formal palettes. These will inform a final independent project. The methods we work with in this class are intended to open possibilities and refine model making skills. Note: The class will have a materials fee to cover workshop costs. There will be some teamwork.

48-234 Introduction to Structures

All Semesters: 3 units

This course introduces structural systems and the materials and elements that make up those systems. Students will study historical and contemporary examples of bridges, long-span roofs, and tall buildings from technical, social, and symbolic perspectives. Through these built works, students will become familiar with structural engineering terminology and the behavior of different structural systems. They will also learn how materials, construction, and non-technical factors influence structural form. Additionally, students will evaluate the aesthetics of large-scale structures and discuss the relationship between engineers and architects. As they learn about structures, students will develop their problem solving skills and ability to communicate ideas by practicing using equations, drawing, and writing.

48-240 History of World Architecture, I

Spring: 9 units

This survey cuts a broad swath through time, geography and cultures, surveying critical episodes in the built environment of Europe, the Middle East, Asia, Africa, and the Americas from ancient times through the nineteenth century. Reflecting the inseparable relation between building and human needs, this course is not only a history of architecture, but also a history through architecture. Over the semester, we will examine architecture as a form of cultural expression unique to its time and place. Through readings and lectures, we will study the ways that the design, use, meaning, and legacy of a building and its site was conditioned not only by the architect's will or the patron's desire, but also by a web of technological, religious, social, cultural, economic, and political factors of the time. There will be several exams over the course of the semester including during finals week.

Course Website: <http://soa.cmu.edu>**48-241 History of Modern Architecture**

Fall: 9 units

This course investigates the global history of modern architecture and theory across the 20th century. We ask critical questions about the canon, the changing nature of history and theory, the biases embedded in terms like "modernism," "progress," and "Non-Western," and the deep legacies of colonialism, globalization, extractivism, and capitalism in which modern architecture so actively participated. After briefly identifying architecture's role in some of the great challenges facing the world today and #8212; climate change, high tech, and social justice and #8212; this course loosely works backward in time following these themes. Along the way we explore major movements of the Euro-American avant-garde and so-called "heroes" of modernism, but also diverse responses to modernity, including vernacular, popular, tropical, and even anti-architecture around the world. We will highlight the role of experimentation and provocation, but also of timeless ideals, local and indigenous traditions, and how they each intersect with the demands of function and technology as well as social and political imperatives. Work for the course falls into four categories: 1) attendance and participation in lectures and discussions; 2) reading, both original documents from the period, and more recent critical histories; 3) writing a series of 2pp. critical reflections on the readings; 4) a semester-long, carefully curated research project on "Non-Canonical" buildings from the Global South in the 20th-century.

Course Website: <http://soa.cmu.edu>**48-250 Urbanism and the Social Production of Space**

Fall: 9 units

Formerly titled "Case Studies in Architecture and Cities" (CSE STD ARC CIT).

48-300 Architecture Design Studio: Praxis Studio 1

Fall: 18 units

Typically, we do site research and then design something for that site. However, this is a studio where the design research part of the semester will become the project itself. We're going to do site research and correlate it with the information we can find. We're going to make unconventional models and experiment with how we construct a network of sites through sets of relationships, linguistic, computational, and visual descriptions. In principle, we're going to think critically about how we construct the identity of a place through its cultural, social, and ecological systems, and develop procedures for doing so. We will investigate Pittsburgh as a collective site. Over the course of the semester, we will develop a "necklace" or circuit of sites that addressing Event, Housing and Infrastructure. The Steel Necklace will be a composite of these three different architectural/urban interventions to address the cultural, social and ecological issues of Pittsburgh. As the urban condition is a network of shared expressions, lived experiences and relationships, our studio will be a collaborative studio exchanging and intermixing projects. Students will detail into the collective network developing in high resolution a housing component relative to infrastructure and event spatial interventions.

Prerequisites: 48-116 and 48-205 Min. grade C and 62-275 and 48-215 and 48-200 Min. grade C and 62-225

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-305 Architecture Design Studio: Praxis Studio 2**

Spring: 18 units

This studio introduces integrated architectural design as the synthesis of disparate elements, demands, and desires. It situates architecture as a technological, cultural, and environmental process that is inherently contingent and entangled, yet tethered to a historical project of autonomy. It is within the contested space between these two notions of architecture that the studio operates. The studio sets out alternatives to extractive practices and introduces students to bio-based material practices and computationally facilitated methods of manufacturing and construction. While the studio directs attention to concerns of building, such as context, building systems, program, and regulatory constraints, it challenges students to situate design as a Project that engages contemporary discourse and ecological imperatives to explore emerging aesthetics, spatial organizations, and materializations. Our discussions and your work this semester will be guided by the following overarching questions: What is architecture's capacity to facilitate civic exchange/life in America today? How might we understand public space today? What are the public spaces, rooms, and interiors of the city in an era of increasing virtuality and privatization of public space? How do building typologies evolve and transform in response to technological and cultural shifts? How can architecture support and reveal the fluid and diverse needs of a community? How might a material-first, carbon-aware approach infuse the design process with greater material specificity and productive constraints? Prerequisite: 48-300

Course Website: <http://soa.cmu.edu>**48-308 Reading and Writing Architecture**

All Semesters: 9 units

As readers and learners, we consume lots of writing about architecture: articles appear in magazines, convincing and polished, finished products for which we struggle to imagine the process. We seldom pause to reflect on how that writing is produced, much less on how we could make writing a tool that works for us. In this collaborative, hands-on class we will work to demystify the process of writing in all its messiness and to highlight its iterative nature. We will explore how various genres of writing work and how architects can use them effectively, not only to communicate with audiences of all kinds but also to explore their own creative ideas. We will read writing about architecture by a number of different voices - architects, critics, historians, journalists, and activists. We will discover from their own approaches to writing what might work for us. We will experiment with writing and editing and explore how text, images and layout may come together to create a cohesive communication strategy. We will focus on becoming sophisticated as consumers and producers of written communication as we are for visual media.

48-310 Prototyping Stories: Experimental Children's Book and Vis Dev as An Architecture

Fall and Spring: 9 units

This design research course explores the current developments in hybrid, multi-platform design and communication mediums to prototype new ways of creative storytelling in architecture, visual development, and concept design. Research methods around oral storytelling, ethno-ecology, radical mapping, and the children's book can allow for the exploration of subjects in ways not available to typical architectural and urban research conventions. Throughout the Fall '23 Term designers will be tasked to use Pittsburgh, PA as a laboratory to develop a research project, from initial concept to an extensive script, including design elements, character development, as well as an urban critique of the city. Frameworks around composition, color, mapping, modeling, the parallel projection, and techniques in painting that are used in architecture, visual development, and concept design will ask how storylines translate and transform in the creation of a comprehensive project using industry techniques. To curate the explorations, we will explore innovative ideas in visual storytelling using techniques of interactivity in children's book design, experimenting with new forms of narrative strategies. The experimentations will result in a final exhibition at the end of Fall 2023.

48-313 Kalla Visiting Faculty Elective

Spring: 9 units

No course description provided.

48-314 Thomas Visiting Faculty Elective

Fall and Spring: 9 units

Coming Soon.

48-315 Environment I: Climate & Energy in Architecture

Fall: 9 units

Our commitment to designing net zero energy and indeed carbon positive buildings and communities is critical to environment equity and the UN Sustainable Development Goals. The U.S. uses more energy per capita than every other industrialized nation without even a guarantee of a shared quality of life. Energy bills can be as much as 25% of all disposable income for low-income households and seniors living solely on social security, and having the power, water or heating shut off is devastating. This course introduces architectural design responses for energy conservation and natural conditioning, human comfort, and the site-specific dynamics of climate. Students will be expected to combine an understanding of the basic laws of comfort and heat flow with the variables of local climate to create energy design guidelines for their own work. The state of the art in building energy conservation and passive heating and cooling technologies will be presented in lectures and supported by readings and assignments. To stress the significance of architectural design decision-making on energy consumption and comfort, full design specifications and calculations will be completed for a residential-scale building. Students will compile a professional energy consultant's report, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management. An overview of world energy consumption in buildings and energy design standards will be illustrated by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. The course will end with a focus on the design integration of natural conditioning systems and the potentially dynamic interface of mechanical systems in small- and large-scale buildings.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-317 The Chair**

All Semesters: 9 units

Making entitles to an intimate connection with the site, native atmosphere, building components, and their assemblies, where a designer/maker can operate at local - regional and global levels comprising all the building systems. This sedulous process takes very closer to the materials where a designer/ maker can gather insights into material behavior (both mechanical and visual) and is better placed to alter the effects of architecture through its materials and generating processes. The same can be applied to chair making. The chair no longer remains a chair, as the making process makes it a ground of experimentation and learning to shape the material into the desired object. The reaction with the matter is no more inert, as it tends to provide feedback to the maker while shaping it. This immersive process of learning by doing in entirety, aids students, in improvising their thought process, the judgment of material behavior, use of the right tool to save material, and developing novel ideas for production and assembly. Prototyping and making largely help develop the understanding concept of joinery/material behavior, and properties in relation to form. The exercise allows understanding chair as a piece of furniture, the manner of making that gives qualities to an abstract design or idea, the know-how of handling material, emergence of tacit knowledge in the maker, and tolerance and feedback from the material.

48-324 Structures/Statics

Fall: 3 units

We examine structural types, structural behavior, material behavior, and construction constraints that underlie our design of buildings, emphasizing the need for a designer to envision a complete 3-D structure. We mostly build "orthogonal structure" constructed in horizontal and vertical planes, requiring high-strength modern materials such as steel or reinforced concrete, comprising roughly 75-80% of the course. This is complemented by "geometric structure" where the three-dimensional shape dictates function; prominent examples include membranes, cable nets, historic masonry domes, and shells. Geometric structure is characterized by "form-finding." Statics underlies all topics, and our treatment is consistent with NCARB expectations.

Course Website: <http://soa.cmu.edu>**48-328 Detailing Architecture**

Spring: 9 units

This course examines the role of the architectural detail in the formation/ thematic development of a work of architecture and how the detail reinforces the theoretical position of the architect. Architectural detailing is often considered only a technical task, but in fact the detail holds the key to inspire, integrate and reinforce the architectural idea as well as the architect's intellectual/ societal position. Many scholars, historians and academics have avoided the detail as a snapshot into the design methodology of architecture. This class is an attempt to do the opposite. The course will consist of a series of weekly lectures, readings, field trips and student developed graphic and physical representations that reveal how the role of detail has played an essential role in the history, evolution and development of the built environment.

Prerequisite: 48-205

Course Website: <http://soa.cmu.edu>**48-332 Teaching and Learning**

Intermittent: 6 units

In this course, students will learn about effective strategies for teaching architecture and the built environment. Topics include the cognitive differences between novices and experts, instructional techniques, and goal alignment. As part of the coursework, each student will implement these teaching strategies to design and teach a lesson. Elements of developmental psychology, learning theories, and classroom practices will inform the architectural education lesson. Teaching and learning techniques can be generalized for communication with clients, practice, and the community.

48-336 Architecture and Agency

All Semesters: 9 units

If buildings consume vast resources and are often embedded in extractive systems of material and labor, how can the agency of architecture be deployed to consider other forms of thinking and praxis? What tactics, strategies, manifestos, and actions can architects deploy to resist, upend, destabilize or reinvent normative mechanisms of architectural production? How do such practices seek new modes of conceiving the architectural project and its concomitant processes; radically reinvent the brief, site, program, material or tectonic capabilities? This course will consider agency simultaneously through historical and contemporary forms of praxis as well as theories that inform them.

Course Website: <http://soa.cmu.edu>

48-338 European Cities in the XIX Century: Planning, Architecture, Preservation

All Semesters: 9 units

The history of the main cities of Europe during the XIX century is a history of change and transformation. The physical environment and the political, financial and administrative structures adapt to the needs of new masses of population and to the challenges of metropolitan life. In some cases, cities even acquire new representative functions, as they become a national capital. This course traditionally offers an overview of the urban culture of XIX century Europe, reconstructing aspects of the broader historical context and then focusing on reading the effects of the XIX century transformations on the physical appearance, structures and image of present-day European cities, such as Paris, London, Berlin, Barcelona, Vienna and Rome. This semester we will add to this analysis, acquired by learning and applying a set of essential questions about XIX century urban transformations, a second look at the image of the city - the issue of how the city is represented and described in the various moments of its Nineteenth century transformation (from historical maps, to paintings, from postcards to literary descriptions). We will try to consider its changing visual representation and the different perception of its character and peculiarities over time, finally discussing how the Nineteenth century image of each city still affects how it is viewed today. We will rely, along with the usual reading materials (articles, book excerpts) also on visual documentation, such as photography and film. The course is based on lectures and discussions and requires personal elaboration, as well as a fair amount of reading and writing.

Prerequisite: 48-240

48-339 IDEATe: Making Things Interactive

Spring: 12 units

In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended. (Participants will provide their own supplies and materials.)

Prerequisites: 60-223 or 16-223

Course Website: <http://soa.cmu.edu>**48-340 Modern Architecture and Theory 1900-1945**

Intermittent: 9 units

This architectural history lecture course surveys the modern buildings and literature of the first half of the twentieth century, focusing primarily on Europe but extending also to non-western countries. We begin with a look at the "crisis of modernity" that plagued most of western civilization in the late 19th-century, and then focus on the major movements of both the avant-garde and other responses to modernity from 1900-1945. The course includes lectures, readings, and discussions about a broad range of issues, including 1) Formal tendencies; 2) Theoretical issues; 3) National traditions; 4) Biographical sketches; 5) Significant technologies and materials; 6) Political motivations; 7) Social and cultural influences. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created, especially the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading and a major research paper.

Prerequisite: 48-240

48-341 Expression in Architecture

Intermittent: 9 units

This architectural history seminar will explore expression in architecture in its many forms, particularly in written works of architectural theory through the ages. We start with the premise that architecture is not merely pragmatic, technical, or functional: it can express or communicate like a language, it can represent and inspire like many of the arts, it can shape behavior and emote, it can trigger memories, emotions, or meanings. As Isozaki put it: "Architecture is a machine for the production of meaning." We'll investigate many ways that architects have theorized the design process, as well as the forms, materials, and contexts of architecture, to express a myriad of ideas and sensibilities. We'll also look at the ways that buildings can communicate and have meaning, often beyond the intent of the architect, and usually changing over time. Some of the topics to be explored include the classical orders, gothic geometry and mystical light, the theatrical space of the Baroque, architecture parlante, character, and style in the Enlightenment, tectonics as structural expression, political architecture and morality, the aesthetics of functionalism, Expressionism, key terms such as ornament, representation, linguistics, and semiotics, as well as more recent theoretical constructs such as embodiment, materiality, atmosphere, and affect. The work of the seminar will include intensive weekly readings, especially of primary sources by the architects seeking to express ideas, weekly presentations and discussions about the sources, and a term paper on an important theory of expression in architecture of your choice.

Prerequisite: 48-240

48-348 Architectural History of Mexico & Guatemala

Intermittent: 9 units

Despite the leveling forces of mass culture and globalization, the geographic and social diversity of the U.S. has created distinctive regional mosaics of landscape and architecture. Say New England and images of English Pilgrims, town greens with white framed churches, and industrial mill villages may come to mind. The Southwest conjures different images, perhaps of adobe pueblos, Spanish friars, arid ranches, and the color turquoise. The built environment of the Midwest, the California coast, the Mississippi Delta, and many places in between reflect particular regional identities that have been both unconsciously and consciously created over time. This course examines the historical development of regional patterns in the American built environment. It investigates how and why a region's architectural identity evolved in the ways that it did. To what degree is place something to respond to, to interact with, and to what degree is place something that is created? Our focus will be primarily pre-20th century when the forces of vernacular traditions were stronger, we will also examine more recent trends of regionalism as an aesthetic choice and a theoretical stance.

Prerequisite: 48-240

48-350 Postwar Modern Architecture and Theory

Intermittent: 9 units

This architectural history lecture course surveys the modern buildings and architectural theory of the post-World War II period. It begins with the cataclysm of WWII and the fundamental shifts it caused on the conception of modernism, technology, cities, and geo-politics. It proceeds to investigate themes such as rebuilding and reconstruction, grand modern masters such as Mies, Kahn, and Le Corbusier, the fascination with technology, megastructures and utopian thought, the need for monumentality, meaning, and regional identity, and the dissemination of modernism from corporate America to the third world. It ends with the rupture in modernism associated with the social revolutions and the rise of a post-modern architecture in the late 1960s and early 1970s. The course includes lectures, readings, and discussions to define the unique character of the postwar period, as modernism both reigned supreme, and began to be questioned. Emphasis will be placed on the relationship of buildings to the more general cultural, intellectual, and historical circumstances in which they were created.

Special attention will be devoted throughout the course to the important manifestoes, theoretical and critical writings that so determined the project of modern architecture. Work for the course involves extensive reading, preparing for class discussions, and a major research paper.

Prerequisites: 48-240 or 48-241

48-355 Perspective

Intermittent: 9 units

This freehand drawing course considers perspective from three understandings of perceptual psychology. Part 1, built on the pedagogy of Kimon Nicolaides, aligns with the Transactionalist understanding of perception. It considers perspective as discovered truth. Part 2 builds on the early work of perceptual psychologist, J.J. Gibson, and aligns with the Ecological position of Gibson and his followers. It considers perspective as an absolute truth of the visual field. Part 3, aligning implicitly with Gestalt psychology, treats perspective as an imposed schema. The course concludes with a final project built around the student's interest.

Prerequisite: 62-126

48-356 Color Drawing

Intermittent: 9 units

48-356 Color Drawing provides practice in the use of color to depict architectural surroundings. Following preliminary exercises using pastels, watercolor is used for most of the course. A central objective is that by the end of the course, students will have good judgement in evaluating color hue, value, and temperature and have gained confidence in the use of watercolor. Coursework assumes some knowledge of linear perspective. Work consists of in-class exercises and weekend assignments built on these. Students can expect to spend up to 6 hours of work per weekend. Prerequisites: (48-126 and 48-121) or (48-135 and 48-130) or (62-126 and 62-125) or (48-125 and 48-120)

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-359 Special Topics: Design Build / Building Systems**

All Semesters: 9 units

In this studio we will consider Thoreau's essay so much of it about his own design/build experience in today's context. Collectively, we will design a cabin to meet the high standards of sustainability set by Eden Hall. After a round of prototyping, testing, and design development, the studio will create a set of construction documents and shop drawings. Covid and funding allowing, we will begin building the cabin at mid-term, with construction continuing into the summer or fall as required. This studio has a nine credit co-requisite, 48-358 Cabin Building Systems, which is also open to CEE students. Its focus will be on the building systems for the cabin that is being developed in the parallel studio. Topics include energy performance (e.g. production, renewable energy systems, passive and active ways to achieve efficiency, and modeling); integrated structural and engineering systems (e.g. building envelope, water treatment and management, heating and cooling systems, and electrical and lighting systems; and sensing for monitoring and control. The class will have a team-based format that is hands-on and lab-oriented rather than a seminar structure, and it will contribute directly to the build part of the studio.

48-367 Material Histories

All Semesters: 9 units

Materials affect the way we engage with a building and carry cultural meanings connected with complex histories, deeply and at times messily intertwined with the social, political and ecological context. In this seminar we will look at the history of the architecture of the last two centuries by following the thread of the history of materials. We will discuss the ways in which buildings of the past and the practice of architecture were affected by which materials were available, how they were produced, and the craft required to work them. We will reflect on how architects interpreted, manipulated, or added to those meanings through their own work. Materials' lifecycles and the networks of extraction, production, transportation, and reuse had an impact on the built environment in the past, just as they do today. We will learn from historical examples to assess the consequences of the choices we make as designers. Finally, we will critically engage with the presence of history as a layer of complexity embedded in the material itself - an effect that is compounded in the practice of reuse of materials with patina, marked from their past use.

48-368 Rediscovering Antiquity: Archaeology for Architects

Spring: 9 units

The course follows the intertwined histories of architecture and archaeology from the mid-eighteenth to the early twentieth century, critically engaging with the outsized influence of classical antiquity on architectural theory and practice and its role of authority and model in the Western artistic and cultural debate. The traces of classical antiquity, buried in the Mediterranean and Middle Eastern landscape, retained part of their cultural significance over the centuries and became the object of a "rediscovery", almost a cultural obsession. Artists, travelers and architects filtered and re-interpreted the reality of ancient objects and places, conjuring up their own vision of the past and nourishing their own creative pursuits from a continuous dialogue with history. At the same time, new political agendas, new biases and new goals were associated with antiquity, influencing the way the past of the region was explored, how the finds were studied and exhibited in residences and Museums, and ultimately creating a stern competition to appropriate this legacy, with deep links to colonialism and imperialism. The ripple effects are still being felt today, for example in the discussion about the repatriation of cultural heritage. We will study the history of this moment to better understand the cultural vantage point that often influenced the fabric of our cities, presided over the creation of many of our cultural institutions and the buildings that represent them, and had a deep and lasting impact on the ideas about architecture and its relationship with history. This will help us grasp more clearly the impact of the "passage to the Modern" and some of the complex and still open issues it brought about.

Prerequisite: 48-205

48-369 Sustainable Architecture and Urbanism for the Gulf Region

Intermittent: 3 units

Ensuring a sustainable built environment in Qatar is critical to sustainable Gulf Region and indeed a sustainable world. The quality of our architecture and urban design can significantly address the challenges of heat, water, energy, mobility, material resources, waste, and health. This course is intended for non-architects to explore the potential of sustainable design for desert climates. Six weeks of explorations and presentations will introduce each student to: Climate analysis for Gulf Region countries and their 'twins' around the world; Green standards for desert climates with their embedded metrics (eg UNSDG, LEED, GreenStar, WELL); and Precedent as a precursor to innovation - a search for great sustainable examples across building types and land use. In-class and homework assignments will create a series of collaborative student slide shows each week. As possible, invited speakers and site visits will be pursued. The final week will be dedicated to a class perspective on the importance of the built environment for carbon and climate change, and student recommendations for building and infrastructure goals for a more sustainable Gulf region. CMU-Q graduates should be dedicated to a more sustainable built environment and understand the design changes needed for sustainability, the benefits to quality of life and to ecological sustainability. Every discipline is a catalyst and a stakeholder in our future - as client, as design/engineer, as consumer, as financier, as scientist.

48-371 City & Suburb: Housing in America after 1850

Intermittent: 9 units

This architectural history course examines the development of American house and housing choices during the period 1850-1975. A recurring picture of the "American Dream" has typically included the image of a single-family, detached dwelling set within its own green yard in the suburbs. However powerful and durable that image is, the history of house and home in America is actually a far more complex story with many different twists and turns. In the course we will look at both urban and suburban housing choices and cultures, ranging from single family detached dwellings to multi-unit housing, and across a social spectrum income, class, race, and gender. Through the use of occasional field trips, we will use Pittsburgh as a touchstone for understanding broader national trends in the history of American urban and suburban housing. The course is organized as a lecture course supplemented with field trips and discussions based on field trips and primary source readings. The additional time slot on Thursday afternoons will be used only when field trips are scheduled. Student work will include a research paper and several shorter written assignments throughout the semester. Prerequisite: 48-240

48-373 Istanbul Constantinople. An Urban History

Fall and Spring: 9 units

A dynamic metropolitan area, with a burgeoning population and rapid urbanization, Istanbul is at the same time a finely woven tangle of historical layers. In this class we will introduce urban history and its methods as we focus on key moments of Istanbul's history. We will delve deeply into the city's powerful and at times competing historical narratives. We will trace the growth and transformation of the urban fabric, discussing Istanbul's role as imperial capital of the Romans, the Byzantines, the Ottomans, its changing fortunes in the twentieth century and the historical roots of the present-day world city. We will discuss cultural specificity and reactions to international models, the challenges of preservation and transformation of the urban fabric and the political making and re-making of its cultural identity. We will also take into account the power of this city to fascinate and inspire through the centuries - the imagined city as a layer of the physical one. Prerequisite: 48-240

48-374 History of Architecture in the Islamic World- A Primer

Fall: 9 units

An introduction to the architecture of the lands where Islam spread over the centuries, this course aims to provide a basic understanding of major epochs and regional variations. We will learn the function and meaning of the most important building types, examine how these types changed over time to adapt to the needs of changing societies and consider influences and exchanges with other traditions. We will examine the historical context within which art and architecture developed and explore critically the lingering signs of those traditions in contemporary society.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-380 Real Estate for Architects

Spring: 6 units

This course explores economic, structural, and political forces that drive real estate development decisions. Through lecture and discussion, real world case studies and simulations, students explore the development cycle from multiple perspectives and gain insight into dynamics that determine if, how, and when projects are realized as well as relationships among architects, developers, and communities. Class attendance and participation is required.

Course Website: <http://soa.cmu.edu>**48-381 Issues of Practice**

Spring: 6 units

This course explores the interdependence of contracts, drawings, specifications, and correspondence and introduces the concept of the Standard of Care. It addresses business development, staff training, and time management and introduces the economic, cultural, and political contexts in which architecture is created. To reflect the pedagogical priorities of the school, social justice related issues related to architecture will be examined. Students will engage with practitioners, consultants, constructors, and others who together form the design and construction team to learn the specific knowledge and skills the team members bring and to understand the importance of collaboration. They will study the effects of owner expectations and field conditions. Students will learn the value of, and path to, licensure, exploring NCARB's licensure path and Architectural Experience Program (AXP). The course describes alternative career paths that would allow students to use knowledge and creative skills gained in their time in the School of Architecture. The class will align with the Professional Ethics and Real Estate courses to provide a comprehensive exploration into the broad profession of architecture and be taught in coordination with the students' concurrent architecture studios so that the students can consider their studio projects from a practitioner's business perspective.

Course Website: <http://soa.cmu.edu>**48-383 Ethics and Decision Making in Architecture**

Intermittent: 6 units

This course investigates ethics for architecture and the built environment. Students will learn about ethics as a discipline, how to identify an ethical issue, and how one might work through an ethical problem. Frameworks will be presented with case studies for practice and discussion. On a macro scale, we will consider the entanglement of architecture with capital as well as sustainability and climate change. We will also touch upon day-to-day concerns regarding safety, zoning, contracts, material selection, internet of things and workplace discrimination. Reading responses and class discussions are the primary format for learning. Each student will also conduct an ethical assessment of one of their studio projects. Non-architects are welcome.

Course Website: <http://soa.cmu.edu>**48-386 PORTFOLIO & RESUME PREPARATION (UG)**

All Semesters: 3 units

No course description provided.

48-390 Physical Computing Studio

Spring: 10 units

This collaborative studio course will allow interdisciplinary teams to develop wearables with a focus on assistive technology. The ubiquitous nature of mobile devices coupled with low-cost and easily integrated sensors and actuators make this a good time to approach real problems for a range of users from the physically disabled to athletes. Teams will learn skills in hardware, software, fabrication, and design communication in order to effectively develop and share their ideas.

Prerequisites: 16-223 Min. grade C or 60-223 Min. grade C

Course Website: <http://ideate.cmu.edu/>**48-400 Architecture Design Studio: Praxis Studio 3**

Fall: 18 units

This studio is the capstone of your undergraduate education and is an opportunity for you to integrate the various technical aspects of your professional degree to date. Each student will have the opportunity to select from one of three proposed building typologies and project scales. As a requirement of this studio, students will participate in student teams developing each project to a high level of technical development. The objective of this studio is to go beyond the typical studio project and to demonstrate the necessary integration within the structural system, building envelope, environmental control systems and life safety system while providing the measurable outcomes of building performance as part of the design process (NAAB student criteria 6). Consultant engineers play an active role in the studio process providing expertise and discussions resembling professional practice. This semester the three studio instructors will be Professors Gerard Damiani, Erica Cochran Hameen and Stephen Lee. Prerequisite: 48-305 Min. grade C

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-405 Advanced Synthesis Options Studio II**

Spring: 18 units

Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities. The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.

Prerequisites: 48-412 and 48-400

48-408 Co-designing an Indigenous Biodiversity Knowledge Learning Space for the Vertica

Spring: 12 units

This is an advanced comprehensive Critical Practice track studio, with one large, complex, semester-long building design project. The studio pedagogy is based on the parallel development of a real project currently being planned, a new performance space for the San Francisco Symphony; it is on the same site and with the same goals and constraints as the actual project. The participation of clients, the professional design team working on these projects, and users is incorporated in the studio's exploration and design process, culminating in review presentations to the client and project team and publication of the body of work. This studio is also a key component of Carnegie Mellon University's Theater Architecture Program, and is offered annually to fourth- and fifth-year students in the Bachelor of Architecture program. The co-Requisite, Theater Architecture Seminar (48:408), provides in-depth research in the typology, analysis of precedents, and the programming and planning of the studio project.

48-409 History and Future of Interaction Design

All Semesters: 9 units

The history of Interaction Design is far richer than what is commonly known among students and teachers, practicing designers and entrepreneurs. Understanding IxD's origins and evolution helps us realize the promises and possibly avoid some of the pitfalls of IxD's future. This course blends readings, lectures, discussions, and prototyping as a means for students to experience this history as if first-hand. Students become immersed in pragmatic yet mind-expanding examples of person-machine interactions such as MEMEX, Musicolour, Hypertext, Dynabook, Fun Palace, Colloquy of Mobiles, Architecture Machine, THOUGHTSTICKER, Architrainer, and Hypercard. Through period articles and subsequent perspectives, students research a handful of historical innovations and then prototype key concepts from that history, forefronting what has been lost in modern commercial implementations. This offers students a hands-on experience of the history of IxD. To explore IxD's future, students are invited to invent their individual future vision of interactive experiences. The course is especially suitable for students with interest or background in interaction design, computational design, responsive architecture, and interactive media.

48-410 Advanced Synthesis Options Studio II

Spring: 18 units

Advances in Artificial Intelligence (AI) and Deep Learning (DL) provide new frameworks for the future of design discipline, while simultaneously questioning the form of authorship and the use of architectural precedent. Offering almost instant resolution of a seemingly complete architectural proposal - the architectural image / sketch can be generated without any design process, prompted solely through natural language in reference to the vast digital archives. Language of architecture typically considers spatial development of architectural forms based on architectural types, elements, programs, and ideologies, while resourcing the historical knowledge of a precedent. However, here the use of architectural reference - especially in context of its ethical implication - might be obscured. This studio will ask how we can expand the design process using AI. What are the consequences of jumping from a narrative into the generation of an instant image, and how does this way of working change design intent, socio-ecological framework, ideological implications and a spatialization process of an architectural proposal. The ambition of this studio will be to examine architecture that inquires into embodied energy as a primary inspiration for formation of matter. The goal is to re-situate design within a hyper-local framework of material resources and life-cycle that positions architecture as a vehicle for ecological and communal restoration. Promoting a shift away from purely data driven rationales, the desire is to engage in the design framed by environmental ethics and sensory subjectivities as part of our collective aesthetic and ecological experience.

Prerequisite: 48-305 Min. grade C

48-425 EX-CHANGE: Exhibition & Publication in Practice

Spring: 3 units

Are you interested in exploring exhibition design, curating, or publishing as part of your practice? This course will give you hands-on experience, inviting you into the process of planning, designing, and curating the 2023 EX-CHANGE, an exhibition and publication that will be launched at the School of Architecture in fall 2023. EX-CHANGE is the School of Architecture's annual exhibition and publication celebrating student work from first year to PhD. Inaugurated in 2017, EX-CHANGE represents an ongoing opportunity to shine new light on the SoA's programs and to position the work within larger questions of research and practice. Students will work alongside EX-CHANGE director Sarah Rafson and the professional design team who have been selected for the 2023 EX-CHANGE to get a glimpse into editorial and curatorial practice. This is an opportunity to play a role in shaping an exciting school-wide event.

48-432 Environment II: Design Integration of Active Building Systems

Fall: 9 units

If there is a benefit to recent global and national upheavals, it may be that we are even more keenly aware of the importance of equity, of social justice, and a more sustainable future. That sustainability must cover the full range of the UN Sustainable Development Goals and your understanding of how you can contribute to a better future through design in the built environment is a primary goal of this course. High performance buildings are achieved with designs that effectively integrate passive and active systems. This course focuses on active systems in commercial buildings and their integration with passive design elements you've studied previously: envelope, ventilation and lighting. We also consider building codes that address outside air requirements for ventilation, and for energy and water efficiency, and discuss where related US building codes lead or lag in promoting exceptional building performance. Environmental sustainability and buildings within the United States receive the greatest emphasis in our work, but we also consider how performance definitions may change where resources like energy or water are limited or unavailable. The active systems covered include lighting, ventilation, heating/cooling, water distribution and water heating, and renewable energy production and amp; storage.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-435 Modern Mexico & Guatemala: 19th-21st Century Architecture**

Fall: 9 units

This course examines the architectural history of modern Mexico and Guatemala, with an emphasis on the 20th century, but drawing on the 19th and 21st centuries as well. We will use architecture as a lens through which we study how both the high-style design vanguards and the vernacular built environment were responses to forces such as industrial modernization, urban growth, economic fluctuation, international relationships, political and social revolution, indigenous discrimination, genocide, and cultural regeneration. Throughout the course we will look at the countries' urban and rural architectural evolution as explicit and implicit expressions of identity (Mexicanidad or Guatemalididad).

Course Website: <http://soa.cmu.edu>**48-438 Modern Mexico & Guatemala: 19th-21st Century Architecture**

All Semesters: 9 units

This course examines the architectural history of modern Mexico and Guatemala, with an emphasis on the 20th century, but drawing on the 19th and 21st centuries as well. We will use architecture as a lens through which we study how both the high-style design vanguards and the vernacular built environment were responses to forces such as industrial modernization, urban growth, economic fluctuation, international relationships, political and social revolution, indigenous discrimination, genocide, and cultural regeneration. Throughout the course we will look at the countries' urban and rural architectural evolution as explicit and implicit expressions of identity (Mexicanidad or Guatemalididad).

48-440 American Regions & Regionalism: An Architectural History of Place, Time, and Cul

Intermittent: 9 units

Despite the homogenizing forces of mass culture and globalization, distinctive regional mosaics of landscape and architecture are still evident across the United States. In this course, we will examine the ways in which the interactions of people, place, and period have created distinctive regional patterns. We will primarily focus on the periods before the 20th century, when the forces of vernacular traditions were strongest, but we will also make forays into more recent trends of regionalism as an aesthetic choice, a theoretical stance, and an intentional place-making device. Students will complete several essays and an independent research project. Non-majors are welcome.

Prerequisite: 48-240

48-442 History of Asian Architecture

Intermittent: 9 units

This course is intended to serve as an introduction to the evolution of urban spaces and the function of the architecture in South Asia, China, Korea and Japan. It is organized chronologically and will examine the impact of indigenous philosophical principles on the organization of villages, capital cities, and religious centers. The course will begin in the Indus Valley where complex urban planning along with public and private architecture flourished from 2600-1900 BCE. We will examine South Asian Hindu and Buddhist cave monasteries as well as freestanding Hindu temples and identify the salient architectural forms that identify each type. We will then move to China where the earliest villages were arranged according to ideas about nature and the organizing system of fengshui. By the earliest Chinese dynastic period, urban planning and building placement were beginning to be codified according to Confucian and Daoist ideals. Later Chinese imperial centers were consciously designed according to Confucian regularity and hierarchy in order to make visual statements about power. We will then move to consider urban organization and Buddhist temples in China, Korea to Japan where South Asian and Eurasian models were adopted and adapted. The examination of the Japanese warrior culture will include castles, new ideas in residential architecture, the Pleasure Quarters, and retirement villas. Contemporary architecture will be addressed through individual and group projects that will investigate specific structures and situate the buildings within the cultural and historic circumstances that led to their creation.

Prerequisite: 48-240

Course Website: <http://soa.cmu.edu>**48-448 History of Sustainable Architecture**

Intermittent: 9 units

The History of Sustainable Architecture investigates themes of nature, ecology, pollution and conservation in the built environment and visual arts. The term 'sustainable architecture' is a comparatively recent one, arising in reaction to the destructive and toxic nature of the industrial era and its strident ambassador, Modern architecture. Yet, an esthetic and philosophical view of harmony with nature accompanies many forms of historical human activity in the built environment. Similarly, issues of waste removal, mechanical systems and natural materials that characterize current concerns have illustrative historical roots in numerous civilizations going back centuries and even millennia in pre-Industrial or non-industrial cultures. This course will engage texts and examples relating not simply architecture, landscape and urban history, but also art, philosophy and popular culture as a means to understand the many precedents for today's interest in sustainable architecture and planning. The course will examine texts and works by figures including Vitruvius, Pliny, Leon Battista Alberti, Thomas Cole, Frederic Law Olmsted, Buckminster Fuller, Reyner Banham, Ebenezer Howard, Hassan Fathy, Bernard Rudofsky, Norman Foster, Robert Smithson, Andy Goldsworthy and more. Students will be encouraged to apply principles from the class to understanding and execution of work in their own discipline.

48-452 Real Estate Design and Development

Fall: 6 units

This course will introduce the Real Estate development process and explore the interdependence of development drivers and the design process. Classroom learning, exercises and guest-lectures will introduce students to the concepts of market and financial analysis, as well as the basic techniques of budgeting, proforma development, and valuation. Parallel to this investigation, students will evaluate real world developments and interface with the development professionals that executed them to learn how development drivers shaped the development process and decision making. Students will study how market demand, tenant requirements, site constraints, and available capital affect feasibility, and through this the ultimate design solution. The semester's effort culminates in the execution of a mini-development project. Students will work in teams to complete a basic market analysis, program evaluation, schematic design, construction and development cost estimate, proforma analysis, and a determination of financial feasibility. Development practitioners will interface with student teams during this mini-project to offer "real world" guidance on student schematic designs and feasibility analysis.

Prerequisite: 48-305

48-453 Urban Design Methods

Fall: 6 units

This undergraduate lecture course introduces urban design history, theory and methods. It is a required supporting course for the Urban Laboratory design studio, and similarly examines urban design at multiple scales: city form and networks, neighborhoods and block structures, streets, public spaces, and urban building typologies. Key issues introduced include the emergence and evolution of urban design as a discipline, economic, social and political factors affecting the contemporary city, and environmental sustainability at the urban scale. A wide variety of cities, projects, proposals and methodologies are examined. Assignments include readings from seminal texts, quizzes, and a final examination.

Prerequisite: 48-305

48-454 Futures of the City/Cities of the Future

Intermittent: 9 units

If all design can be read as attempts to predict and to shape the future, then no one looks further into the future than the urban designer and the urban planner. The work in which they are involved often does not materialize in their lifetimes; in fact, the duration of the projects are so long twenty, thirty, fifty and hundred year timeframes, it is more than likely that he or she will pass on before the project reaches fruition. The trouble with predicting the future is that it is so uncertain, so undecided, so unknowable. A brief look backwards reveals that we are not the first generation to consider the future. History is replete with predictions, some of which were actualized, the vast majority of which were not. Today's forecasts for tomorrow vary wildly. A handful of optimists view the future through rose colored glasses, whereby humanity is delivered to salvation via technological wonders and the widespread adoption of common social values. A larger group predicts the end of the world as we now know it, but even they cannot agree on the cause of our demise, with those arguing that climate change will kill us clashing with those convinced that we will be destroyed when robots achieve technological singularity. Shy of total extinction, however, any vision of the future requires designers, and will likely occur in urban (or formerly urban) locations. As of this decade, for the first time in history, more than half of the world's population, almost three and a half billion people, live in towns and cities. Estimates suggest that by 2030 this number will swell to almost five billion.

Prerequisite: 48-205

48-459 Material Simulacra

All Semesters: 9 units

This fabrication-based course interprets Jean Baudrillard's ideas of "panic-stricken production of the real and the referential, above and parallel to the panic of material production." Serial mold-generated surface studies activated by material properties, behavior, intuition, and expression ask how our perceptions of the real is mediated by language of the made artifact. Structured as the tripartite investigation: TheoryResearch-Craft, this seminar's pedagogy is centered on the cultural, historical, ethical, aesthetic and tectonic values of architectural materialism to arrive at an awareness of what a material conveys. Analog and digital techniques and simulations engage the technological and intellectual roles of the craftsman.

Course Website: <http://soa.cmu.edu>**48-467 Design Build Elective**

Spring: 9 units

In this course, students will work on an interdisciplinary, design-build project to improve the quality of life through design interventions on campus. The semester will begin with a review of design proposals developed during the Fall semester, and through a collaborative process the class will determine what can be built given budgetary and workforce constraints. Students will complete construction documents, develop project management plans, build full scale prototypes, procure materials, and construct the designs.

Course Website: <http://soa.cmu.edu>**48-470 The Depth of Surface**

Fall: 9 units

Lamination is the process of gluing wood together along the edge or face of a plank. There is unlimited variety in the ways to do this and to generate pattern in the process. This course will prescribe a few basic ways to laminate following standard rules of wood working and then introduce the possibilities of pattern generation. Generally lamination is unidirectional, however, in this class we will introduce ways to achieve cross directional patterning and the use of inlay to elaborate on the idea of patterning. Projects will be visual and sculptural statements. Their function will be limited and will not be furniture. Each exercise will present a series of basic wood working operations, which, when repeated and recombined will become products of compelling visual character. As visual idea statements you will be asked to experiment, invent and explore and take these standard operations in new directions. As visual idea statements the greatest clarity of vision will be achieved through careful construction.

48-473 Hand and Machine Joinery, New Directions

Fall: 9 units

In the Fall 2017 and Spring 2018 there will be some changes to the shop electives offered. First the Spring Furniture Design and Construction course # 48564 will no longer be offered because that content is incorporated within the Furniture Studio in the fall. Next, the two shop mini courses previously offered in the fall will each be expanded to become full electives, one in the fall and one in the spring. The prerequisite for both of these classes is documentable experience with the band saw, table saw (ripping and crosscut), drill press and the belt and disk sander. The Hand and Machine Joinery, New Directions, is scheduled Tuesday and Thursday mornings 10:30 am to 11:50 in the spring 2018, and will be a 9 unit elective running the entire semester. The elective will focus on building a free standing (or hung) cabinet with doors. If enrolled students have taken the Exploring Pattern course in the fall the doors made in that class will be mounted on the cabinet. If students have not taken that course then a pair of simple doors will be made instead. The primary goal of this course will be to learn the steps of making a simple cabinet using hand and machine joinery. Quality of craft will be of great importance. Uniqueness of design will not be emphasized, however individuation of the cabinet will still be possible throughout the construction, starting with choices between a wall mounted or free standing (with legs) cabinet, the selection of hardwoods, the specific size of parts, and the selection of particular detail options. The construction process will be carefully staged with demonstrations continuing throughout the semester. The cabinet will be perpendicular and rectangular. Students will use standard mortise and tenons of various sizes, bridal joints, floating tenons, tongue and groove, spline and dovetail joints.

48-478 Digital Tooling

All Semesters: 6 units

This course serves as an immersive analysis of the available technologies located in the Digital Fabrication Lab at Carnegie Mellon and beyond. Students begin to understand equipment limits/boundaries, purposes and concepts; and the possibilities that arise from thoroughly comprehending how these tools work. During your Digital Experience, students begin to understand more systematically how to use these tools to their advantage. A better understanding of the equipment proves very useful towards a SoArch Student's 3rd, 4th and 5th years at Carnegie Mellon; but more importantly provides a fundamental understanding of a leading edge technology that will certainly prove itself as an integral tool for any Designer throughout their professional career. It is based on the idea that pushing the limits of design fabrication; comes from knowing the limits of your tools. The course operates by discovering tooling extremes; thus indicating limits, and then incorporating these boundaries (and/or breaking them) with Digital Fabrication methods and tooling; ultimately providing a platform in which students begin to understand and incorporate project efficiency. Prerequisites: Imagination, Laser Cutting, Milling and 3D-Modeling Experience required. (Rhinoceros 3D Preferred)

Prerequisite: 48-205

48-485 Design and Documentation in Revit

Fall and Spring: 3 units

This course will guide you through the process of designing in Revit from the schematic, conceptual design phase, to the construction document phase. The course will start with basic concepts moving on to more advanced topics. Layering information and how much to incorporate into the model, based on stakeholders and end users, will be discussed. Capturing the essential information from the BIM model will be explored to develop presentations, bidding documents, and construction documents to relay relevant information to clients, consultants, and contractors. We will discuss when it is imperative to model in 3D and when to overlay 2D linework detail. Real-time rendering techniques that streamline the design process will be explored using Enscape. The skills learned from this course will help you understand the phases of design and documentation in the Revit environment.

48-486 Systems, Cybernetics, Conversation

All Semesters: 9 units

Across many design disciplines architecture and computational design, media and interaction design, design of services and organizations methods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

48-493 Representing Activism

Intermittent: 9 units

Efforts to promote social, political, economic and environmental change range in form from written word to direct action. Sources of injustice that those efforts address are multi-dimensional and complex. Effective forms of activism are fueled by creativity that synthesizes and distill complex constellations of information and foster understanding. REPRESENTING ACTIVISM explores the role of multi-media graphic representation as a lens through which change and social justice can be fostered. Exploration of efficacy in application will span four dimensions, 1) Social Media, 2) Film, 3) Poster/Graphic Design, and 4) Publication - all aspiring to achieve the status of art. Art and Activism are predicated on exposing the truth. Art has the unique power to convey messages across linguistic and cultural barriers that often divide. Part of the Activist's challenge is to grip and inspire people to action. With the avalanche of information and media modern society absorbs every day, this is increasingly hard to do. Sometimes it is too much to ask people to stop and think: sometimes it's too much just to ask them to stop. Successful art compels this, penetrating apathy and imploring the viewer to look deeper and explore the narrative that is embedded in what elicited a visceral response. This seminar aspires to compel action in the public interest through artful representation.

48-494 Beyond Patronage

Intermittent: 9 units

TBD

48-497 Pre-Thesis

Spring: 3 units

This 3 unit course is designed for B.Arch and M.Arch students a year before their final Spring semester. The course develops an understanding of research methods, and explores the formation of ideas for architecture thesis projects. Many directions of architectural thinking (spatial, material, ideological and procedural), will be discussed and in framing a theoretical position we will see how an architecture thesis can use a creative process to discover and express findings in relation to large questions and to disciplinary discussions. This is a required course for Fall Thesis Seminar in F23 (9units) and Spring Thesis ASOS S24 (18units).

Course Website: <http://soa.cmu.edu>**48-500 Advanced Synthesis Options Studio**

Fall

Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities. The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.

Prerequisite: 48-410

48-505 Advanced Synthesis Options Studio III

Spring: 18 units

Having proven competency in the spectrum of skills determined necessary for tomorrow's architect during the first three years of the program, students in their fourth and fifth year are permitted to select from a variety of studio options, each providing the opportunity to build upon or augment some of those skills with new or more nuanced perspectives. All advanced synthesis studios are open to both years, the vertical integration offering enhanced learning opportunities. The content and focus of each studio is governed by faculty interests, which run the spectrum of architectural pursuits, ranging in scale from the design of a piece of furniture to a city and in approach from a comprehensive and complex building program to a critically-driven speculation. They may also be interdisciplinary in nature, taking advantage of the unique juxtapositions made possible at Carnegie Mellon.

Prerequisite: 48-105

48-509 Architecture Design Studio: Thesis I/ Independent Project

Spring: 18 units

This is a year-long, independently defined research and design project that takes the place of upper level option studios. Thesis is an opportunity to develop skills, thoughts, and habits essential for future success, including mental discipline; independence of mind and judgment; working with advisors; the capacity to focus and pursue a subject in depth and over an extended time; the ability to design and execute a complex project; the skills of analysis, synthesis, and clear writing; and the self-confidence that grows from mastering a difficult challenge. Thesis topics and research agendas are generated by the student, but must be determined in collaboration with an advising team, and approved by a Thesis Coordinator. The School seeks to encourage an expansive range of rigorous and provocative inquiry as a culminating experience for the B.Arch education, including work that speculates, invents, or improves on existing ideas, practices, or systems through research and design; work that challenges the boundaries of the discipline and the profession, and moves beyond mere practice or solution-based work; work that engages with open-ended and generalizable ideas, as much as with specific situations; work that projects or imagines a better future and an improved world; work that leads to the new knowledge, ideas, understanding, or paradigms. Acceptance into Thesis is dependent on passing the 48-497 ?Thesis Prep? course or its pre-approved equivalent, and submitting a rigorous thesis proposal to the Thesis Coordinator in late August, before the begin of classes. Approval for the 2nd semester is contingent upon successful completion of the 1st.

48-510 Advanced Synthesis Options Studio IV

Spring: 18 units

Advances in Artificial Intelligence (AI) and Deep Learning (DL) provide new frameworks for the future of design discipline, while simultaneously questioning the form of authorship and the use of architectural precedent. Offering almost instant resolution of a seemingly complete architectural proposal - the architectural image / sketch can be generated without any design process, prompted solely through natural language in reference to the vast digital archives. Language of architecture typically considers spatial development of architectural forms based on architectural types, elements, programs, and ideologies, while resourcing the historical knowledge of a precedent. However, here the use of architectural reference - especially in context of its ethical implication - might be obscured. This studio will ask how we can expand the design process using AI. What are the consequences of jumping from a narrative into the generation of an instant image, and how does this way of working change design intent, socio-ecological framework, ideological implications and a spatialization process of an architectural proposal. The ambition of this studio will be to examine architecture that inquires into embodied energy as a primary inspiration for formation of matter. The goal is to re-situate design within a hyper-local framework of material resources and life-cycle that positions architecture as a vehicle for ecological and communal restoration. Promoting a shift away from purely data driven rationales, the desire is to engage in the design framed by environmental ethics and sensory subjectivities as part of our collective aesthetic and ecological experience.

Prerequisites: 48-400 Min. grade C or 48-410 Min. grade C

48-516 NOMAS

All Semesters: 3 units

TBD

Prerequisite: 48-105

48-517 Carnival Gateway Project Management

Spring: 9 units

This course is for the team responsible for the design and project management of the Carnival Entryway Pavilion, to be completed for the 2023 CMU Carnival, April 13-15. The course is conducted by NOMAS and advised by Professor Vicky Achmani.

48-519 Architecture Design Studio: Thesis II/ Independent Project

Spring

Thesis is a year-long, independently defined research and design project that takes the place of upper level option studios. Thesis is an opportunity to develop skills, thoughts, and habits essential for future success, including mental discipline; independence of mind and judgment; working with advisors; the capacity to focus and pursue a subject in depth and over an extended time; the ability to design and execute a complex project; the skills of analysis, synthesis, and clear writing; and the self-confidence that grows from mastering a difficult challenge. Thesis topics and research agendas are generated by the student, but must be determined in collaboration with an advising team, and approved by a Thesis Coordinator. The School seeks to encourage an expansive range of rigorous and provocative inquiry as a culminating experience for the B.Arch education, including work that speculates, invents, or improves on existing ideas, practices, or systems through research and design; work that challenges the boundaries of the discipline and the profession, and moves beyond mere practice or solution-based work; work that engages with open-ended and generalizable ideas, as much as with specific situations; work that projects or imagines a better future and an improved world; work that leads to the new knowledge, ideas, understanding, or paradigms. Acceptance into Thesis is dependent on passing the 48-497 ?Thesis Prep? course or its pre-approved equivalent, and submitting a rigorous thesis proposal to the Thesis Coordinator in late August, before the begin of classes.

Course Website: <http://soa.cmu.edu>**48-524 Building Performance Modeling**

Fall: 9 units

"You can't hammer a nail over the Internet" Matthew B. Crawford, Shop Class as Soulcraft: An Inquiry Into the Value of Work The Design/ Build ASO Studio is part of a year-long, interdisciplinary, design-build project to provide a diverse group of students with the opportunity to work with their eyes, hands, and brains to transform an idea from a virtual world into the physical world. The elective is an opportunity for any student to join the spring "build" activity for 9 units. In this semester, we will again work campus constituents to improve the quality of life on campus through engaging design intervention(s). The project is fully funded, and the expectation is that the project will be turned over to the campus community by the last day of classes in the spring semester. During the fall, the Building Integration Option Studio (BIOS) students envisioned a farmer's market for Hazelwood Green creating design proposals at three scales-XL-M-XS. These design proposals for "XS" components will be a potential launching point for the spring build experience. These designs are just that-launching points-they have not been considered in the context of the Carnegie Mellon campus, so design will be a critical component of the early spring.

Prerequisite: 48-305 Min. grade C

Course Website: <https://omerkaraguzelphd.wixsite.com/praxismodeling> (<https://omerkaraguzelphd.wixsite.com/praxismodeling/>)**48-525 Thesis Seminar**

All Semesters: 9 units

This seminar is designed to prepare students planning to work on a thesis project in the B.Arch and M.Arch programs. Thesis work is highly self-directed and requires a level of metacognitive thinking, which includes identifying a valid area of concern, understanding the disciplinary discourse around a chosen topic and its cultural and social context, identifying the means and methods to implement the project, and establishing the criteria by which to evaluate the work. This course is structured around the individual effort required to advance these aims. You will enter this course with an initial thesis statement, a body of background research related to your topic, and a set of questions that can be interrogated by engaging in research and discussion. The seminar will help you refine the scope of the thesis argument, define appropriate research methods, sharpen communication about thesis work in all of its phases. In addition, it will facilitate group conversation and exchange of ideas, providing dialogue, feedback, and continued motivation. The collective engagement of all seminar participants, in addition to individual conversations and targeted feedback from the instructor, will support your sustained progress.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-527 5th-Year/Senior Seminar**

Intermittent: 3 units

Seminar for students graduating from the Bachelor of Architecture and Bachelor of Arts in Architecture programs.

Course Website: <http://soa.cmu.edu>**48-528 IDEaTE: Responsive Mobile Environments**

Intermittent: 9 units

As part of this project-based course, we'll get hands-on with emerging technologies, concepts and applications in the Internet of Things through a critical lens. We'll prototype everyday intelligences and design smart and connected devices that examine and speculate on the strange, supernatural, and mystic qualities of the smart home. The first half of the semester will introduce students to building connected devices and intelligent spaces through technical development workshops, readings, applied explorations, and guest lectures. The second half of the semester will be organized as an applied collaborative project.

Course Website: <http://daraghbyrne.me/teaching/responsive-mobile-environments/>**48-530 Human-Machine Virtuosity**

Spring: 12 units

Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

48-531 Fabricating Customization: Prototype

Intermittent: 9 units

Architects have long flirted with production and manufacturing. From the early days of the Bauhaus and Walter Gropius' experiments with factory-built housing to Jean Prouvé's design and manufacturing of architectural components to Ray and Charles Eames' interest in the social potential of mass production, architecture has long been enamored by the promise of technological advancements in manufacturing. This has been pursued to yield greater affordability and accessibility, customization, and expression, and as of late, more carbon-aware material selection and manufacturing. This course builds upon this rich history and foregrounds architectural component customization to explore prototyping and customization within the context of contemporary practice. It introduces students to a range of prototyping and design for manufacturing frameworks. Through case studies and guest lectures, the course leverages techniques of digital manufacturing and fabrication. It offers students an overview of existing and emerging modes of collaboration between designer and manufacturer in service to the production of a customized building component. The course places great emphasis upon the reciprocity of design and prototyping, challenging students to leverage physical artifacts as tools for thinking and testing. Throughout the semester, students will utilize additive and subtractive fabrication techniques to iterate the design of architectural components. Through this process, students will build proficiency in prototyping to design, test, and refine components of limited scope and scale.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-541 The Cut, The Beach and Beyond**

All Semesters

The Cut, the Beach and Beyond will be a FALL design elective with a SPRING build option studio working with Campus Design and Facility Development, the Department of Civil and Environmental Engineering and campus constituents to improve the quality of life through design intervention(s) on campus.

48-543 Color Constructs

All Semesters

In this course you will study and experiment with the relationships and perception of space and form through two- and three-dimensional optical experiments using color. Lectures, discussions, and field trips will delve into color theory particularly focused on the work of artist, designer, and educator Joseph Albers, look at culturally defined use of color, and its experience. In keeping with Albers definition of color theory as a hands-on experiential and experimental process of creating relationships through perception students will work on skills needed to craft compelling images using linear, planar and volumetric assemblies in digital and analog media. Initial weekly exercises will cover principles of color relativity, intensity, temperature, etc., and consider various principles of graphic perception including but not limited to vibrating and vanishing boundaries, figure ground reversals, and the illusion of transparency. Through this process you will gain an understanding of the use of color in the graphic representation of designs, patterns, diagrams and architectural representations that will inform the use of color in transforming the perception of space. The final assignment will be a three-dimensional color structure.

Course Website: <http://soa.cmu.edu>**48-545 Design Fabrication**

Spring: 9 units

Design Fabrication is a project based seminar exploring the application of Computer Aided Manufacturing (CAM) in architecture. The course meets in the School of Architecture's Design Fabrication Lab (dFAB), which serves as a context to better understand the interconnected affordances of building materials, machine processes, and modeling software for design thinking. During the semester students receive hands-on introductions to dFAB equipment, including laser cutting, cnc routing, and 3D printing. Concepts will be explored and tested through iterative making/prototyping. Course Focus The course focuses on Transdimensional Fabrication, a manufacturing framework that forefronts design thinking across space and time. A growing array of approaches in contemporary architecture are motivated by this focus (e.g. flat pack, 4D printing, metamaterials, kinetic architecture, robotic origami, design for disassembly, etc.). We will investigate Transdimensional Fabrication concepts through three that forefront design translations: 2D 3D, Space Time, Assembly Reconfiguration Disassembly

Course Website: <http://soa.cmu.edu>**48-550 Issues of Practice**

Fall: 9 units

Issues of Practice is a required course taught in the fifth year. It consists of three modules: Personal Promotion, Emerging Professional's Companion, and Excursions. The Personal Promotion module provides the students with a framework to create a resume, cover letter, and portfolio. The EPC (Emerging Professional's Companion) provides concentrated study in different aspects of professional practice. The Excursions require students to see how architecture relates to the wider world with architecturally related events that can include volunteer opportunities, lectures, mentorship, or teaching.

Prerequisite: 48-305

48-551 Ethics and Decision Making in Architecture

Spring: 9 units

Ethical Decision Making in Architecture is a required course in the fifth year of the Bachelor of Architecture Degree. It is part of a sequence dealing with professional aspects of the field of architecture, alongside courses like Human Factors, Real Estate Design and Development, and Issues of Practice. It builds on an understanding of the issues of occupancy, economics and practice in design decision making. The course covers basic frameworks of decision making and ethical adjudication through several case studies including Fallingwater, Sydney Opera House, Citicorp Tower, Pruitt-Igoe housing development, Crystal Palace and Kansas City Hyatt. The text for the course is a manuscript by the instructor entitled "Ethical Decision Making in Architecture".

Prerequisite: 48-205

48-554 Entangled: Remaking Nature from the Picturesque to the Hypernatural

All Semesters: 9 units

This seminar questions how we perceive, represent, and reconstruct our world in relation to evolving concepts of "nature" and their manifestation in architecture, art, and landscape. It is focused on the intellectual trajectories that define ecology and environment to arrive at the paradigm shift theoretician Donna Haraway has termed natureculture. We will first familiarize ourselves with historical ways of seeing "nature" and how this has formed the landscapes of the Anthropocene. This will help us put a critical lens on land, environmental and ecological art, ecoventions, architectural living systems, biomimicry, biophilia, and projective ecologies while we consider the influence of gardens, responsive landscapes, hyper-natures, and artificial ecologies in changing the way we design and build. We look for not only relevance but joy and beauty in practices that highlight the relation between desire, responsibility, more-than-human wellbeing, and ecological justice. This may help us build notions of care and stewardship and an understanding traditional and emergent cultural constructs that can define an eco-centric practice which shapes building futures. The course surveys texts from a range of topics including ecological aesthetics, architecture, art, landscape urbanism, and ecologically focused philosophy and theory. It includes weekly readings, discussions, presentations, and visual or written deliverables. Open to graduate and undergraduate students in Architecture and allied fields.

48-555 Introduction to Architectural Robotics

Fall: 9 units

This course provides an introduction to industrial robotics and automated fabrication within the field of Architecture. A series of lectures will cover the basic components, as well as their work flows, needed to design flexible automation - while work sessions will develop skills in hands-on programming, RAPID, work flow simulation, fixtures, and sensors. We will also issue competency-building projects within the lab environment in order to provide students with hands-on experience using the equipment. Upon covering the fundamental software and hardware content, an end-of-semester project will challenge you to apply your newfound knowledge to solve a final prompt. This is a portal course to all sanctioned coursework using the School of Architecture's Robotic Fabrication Lab. Upon successful completion, students will be eligible and prepared to enroll in advanced robotic fabrication courses.

48-557 Formless as an Operation

All Semesters: 9 units

This seminar focuses on the formless as an operation relative to social constructs, parametrics and aesthetics. Geometry is often thought of as a rational or a structure that secures and grounds things, however the structures of the built environment is an unfolding and indeterminate product. Social constructs can be defined as formless or the informe, as coined by George Bataille; an operational existence. In expanding the one's idea of operating, the use of formless allows us to consider the indeterminate. The indeterminate for our purpose in exploring context relative to spatial and cultural traditions. Within social and political space, traditions become spatial operators. How can we spatialize and draw traditions, rituals, and narratives? We will investigate the means and methods of representation relative to the formless and the built environment. Participants in the seminar develop an archive, original visualizations that utilizes multiple mediums and platforms, and culminate in a final project a part of an exhibition.

Course Website: <http://soa.cmu.edu>**48-558 Reality Computing**

Fall: 12 units

Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented reality / virtual reality, 3d printing, robotics). This semester the studio will focus on utilizing these technologies to capture places and objects to digitally recreate them for archives, artifacts, and interactive experiences. We will explore and analyze how to optimize these creations for real-time rendering and analyze how these platforms bridge the divide between "virtual" and "real."

48-560 Histories of Urban Design

Fall: 9 units

This architectural and urban design history course examines the cultural histories of the design and redesign of world cities. The scale of urban interventions we will look at varies greatly, from the macro-scale of designing totally new capitals to the micro-scale of altering small nodes within a city. We explore the relationship between form and culture by considering political, social, economic, and aesthetic forces that have shaped the public realm of urban as well as suburban spaces. We focus on recognizing and understanding the rationale behind the design, re-design, and use of culturally important urban spaces during their own time, making periodic forays into the issues that influence those spaces today. Non-majors are welcome.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-564 Furniture Design & Construction**

Spring: 9 units

This course is for students who already have a basic knowledge of hand tools and machines, and standard fabrication methods. Wood is the primary material, although other supplemental materials are permitted. One functional project will be built during the semester. Because all the equipment in the shop is traditional analog, the fabrication will remain analog. All operations will be done with hand tools or machines operated and controlled by hand. The emphasis of the design phases will also be non-digital. However recognizing the versatility of CAD, students will be permitted to advance and refine their ideas using their computer. One full scale orthographic drawing by hand will still be required, including plan, elevations, sections, and dimensions on 1/8" ply or mdf. Prerequisites: 48-105 and (48-470 or 48-473)

48-568 Advanced CAD, BIM, and 3D Visualization

Fall: 9 units

This course is designed to introduce a student to 3D software tools, including AutoCAD 3D, Revit Architecture, and 3D Studio MAX. Using building information and parametric modeling, materials, lighting, rendering, and animation students will create integrated CAD/BIM projects, 3D video animations, and realistic renderings. The course objectives are to develop an understanding of how to properly set up and manipulate 3D projects integrating software applications, replicating real world projects in leading architectural, lighting, and design firms; learn how to create details 3D CAD models using surfaces and solids; learn about BIM parametric modeling using Revit Architecture; and learn how to apply materials, lighting, and rendering to AutoCAD, Revit, and 3D Studio Max. At the conclusion of this course, students will have projects and animations created and architectural CAD/BIM standards outlined. Students should have some familiarity with basic AutoCAD 2D commands. Those who don't have AutoCAD 2D knowledge can contact the professor to arrange for on-line tutorials that need to be completed before classes begin. This course will be primarily taught asynchronously via video lectures and other materials. Some live remote meetings will be held for topic previews and project reviews. Remote office hours will be held weekly. Prerequisite: 48-305

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-569 GIS/CAFM**

Spring: 9 units

A Geographic Information System (GIS) provides storage, retrieval, visualization, and analysis of geographically referenced data. GIS provides analytical tools to investigate spatial relationships, patterns, and processes of location-based data such as cultural, demographic, economic, environmental, health, physical, social, and other phenomena. GIS creates digital twins (virtual representations) of natural and built environments and integrates many types of digital models. GIS topics include geographic concepts (projections and map scales), map design, geodatabases (importing spatial and attribute data, geocodes, table joins, and data aggregation), spatial data processing, digitizing, data mining, multivariate cluster analysis, drive and walk time networking, raster GIS, spatial statistics (proximity and hot spot analysis), animation, and 3D GIS. CAFM (Computer Aided Facility Management) and IWMS (Integrated Work Management Systems) topics include space and asset management, building operations, environmental health and safety, and real property. The course includes in-person and asynchronous video lectures to learn important GIS concepts and a brief introduction to work management systems. Software tutorials cover leading GIS software from Esri Inc. Applications include ArcGIS Pro, ArcGIS Online, ArcGIS Map Viewer, ArcGIS Story Maps, and Dashboards. Subject areas are related to architecture, engineering, construction management, building performance, environmental health, sustainability, public policy, urban design, and planning. Prerequisite: 48-205

Course Website: <http://soa.cmu.edu>**48-576 Mapping Urbanism**

Intermittent: 9 units

This seminar provides the critical tools necessary to examine the city as both a representation and a reality in flux. Through an interdisciplinary framework, students study urban history, theory, visual thinking and spatial mapping. Contemporary urban issues are introduced through weekly lectures, readings, and class discussions. Parallel to these urban explorations, students learn to employ a diverse set of representational techniques to create inventive mappings. Upper-level (300 and 400 level) undergraduate students and graduate students are encouraged to register.

48-587 Architecture Lighting Design

Intermittent: 9 units

Through hands-on exploration of light students will develop a design process for lighting public spaces. All classes will be held in a fully equipped light lab to give the students full access to experimenting with light in design applications. Understanding how light creates focus and mood will be explored in class lab exercises. Discussion topics will include the role of the architectural lighting designer in the collaboration process, establishing design goals and a lighting point of view, communicating design ideas, analyzing successful lighting design in case studies for interior and exterior applications, and becoming familiar with the technical tools of lighting design. The final design project will include lighting mock-ups of a building site.

Prerequisite: 48-105

Course Website: <http://soa.cmu.edu>

48-596 LEED Buildings and Green Design

Spring: 6 units

Green building and sustainable design have been rapidly gaining acceptance in all sectors of the building market. Global issues of energy use, emissions, resource depletion, and land use are forcing building professionals to re-evaluate standard design and construction processes, and look to more environmentally friendly practices. The U.S. Green Building Council (USGBC) developed green building rating systems entitled Leadership in Energy and Environmental Design (LEEDTM) in order to define "green building" by establishing a common standard of measurement. LEED considers green building methods and technologies in several categories including site, water, energy, materials, and indoor air quality, and awards points towards an overall green building rating of certified, silver, gold or platinum. Currently, LEED registered projects make up 3% of the current U.S. commercial building market, and Pennsylvania is the third leading state with LEED registered projects. There is now a demand for design professionals with knowledge and experience not only in sustainable design but specifically with the LEED rating system as well. This course will provide students with background knowledge of the USGBC, the LEED system, as well as referenced standards related to specific topics. The course will benefit greatly from the large number of LEED projects in the Pittsburgh region, which will serve as case studies. Upon completion of the course, students will be prepared to take the LEED Professional Accreditation Exam, which is quickly becoming the standard of recognition for green building professionals.

Prerequisite: 48-315

48-607 Architectural Agency

All Semesters

Coming Soon

48-608 Co-designing an Indigenous Biodiversity Knowledge Learning Space for the Vertica

Fall and Spring: 12 units

The seminar emerges from the instructor's work while co-founding the "Vertical University" project in Nepal. As a subversion to the traditional way we understand knowledge, the "Vertical University" builds on the learning potential inherent in the place-based, deep-seated indigenous knowledge of farmers living in biodiversity-rich landscapes. The project spans across a vertical gradient starting at a 67-meter elevation in Koshi Tappu to Mount Kanchenjunga (the third tallest peak in the world) at 8,586 meters. For us, farmers are the professors; the villages are the classrooms, and the 8-000 meter vertical gradient is the "Vertical University." Across this belt, the project is anchored in six regions. However, the seminar will be focused on Kurule-Tenupa, a community where these imaginative ideas and aspirations come to life. A local community-based learning ground on 16 acres of land has been established under the leadership of local indigenous leaders. Through this elective and collectively with the community (online), we'll design this library as a new repository of knowledge that reinforces the local indigenous communities' relationship with their ecology. This production seminar aims to generate a design for the Indigenous Knowledge Library, which will be built in Kurule-Tenupa. If successful, this important typology, we hope, will be replicated in other parts of the project and, hopefully, throughout Nepal.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-610 Prototyping Stories: Experimental Children's Book and Vis Dev as An Architectura**

Fall and Spring: 9 units

This design research course explores the current developments in hybrid, multi-platform design and communication mediums to prototype new ways of creative storytelling in architecture, visual development, and concept design. Research methods around oral storytelling, ethno-ecology, radical mapping, and the children's book can allow for the exploration of subjects in ways not available to typical architectural and urban research conventions. Throughout the Fall '23 Term designers will be tasked to use Pittsburgh, PA as a laboratory to develop a research project, from initial concept to an extensive script, including design elements, character development, as well as an urban critique of the city. Frameworks around composition, color, mapping, modeling, the parallel projection, and techniques in painting that are used in architecture, visual development, and concept design will ask how storylines translate and transform in the creation of a comprehensive project using industry techniques. To curate the explorations, we will explore innovative ideas in visual storytelling using techniques of interactivity in children's book design, experimenting with new forms of narrative strategies. The experimentations will result in a final exhibition at the end of Fall 2023.

48-611 On Speed / Space, Time & Information

All Semesters: 9 units

This seminar focuses on relations between architecture, information and computing technologies, and society as they are conditioned by speed: rates of transfer, response, exchange, movement, cognition, and more. Development in the last century has been marked nearly always by new velocities, at times testing or altering human tolerances for construction, for perception, for adaptation, for reliance on shelter and on computational systems. These roles of speed reveal ways that architecture and information systems embody shifts in culture, in technology, and in society - but also shifts in less obvious things like the emergence of global finance and geopolitics. Since late Capitalism and the rise of post/industrial economies, these shifts continue as indicators for unprecedented ecological and economic phenomena. Speed, in short, is not neutral or relative but always a function of its circumstance. In readings and class discussions, we will consider roles of speed in things like modular construction and shifts to rapid prototyping and fabrication; in the dissemination of Cybernetic thought; in evolving forms of public space with new telecommunications technologies; and in ecologies of material use. Readings in architecture, in media theory, in philosophy and more will explore ways that time is understood, is constructed in different ways, and to different ends. The seminar culminates with the recent movements toward "accelerationism" - rushing modernism and capitalism to some logical conclusions - and an interest in experiences beyond human perception in slowness.

Course Website: <http://soa.cmu.edu>**48-613 Kalla Visiting Faculty Elective**

All Semesters: 9 units

Coming Soon.

48-614 Thomas Visiting Faculty Elective

All Semesters: 9 units

Coming Soon.

48-621 Beyond the Buildings Footprint

All Semesters: 9 units

This project-based seminar explores the use of machine learning and other software to create a speculative future for Braddock, Pennsylvania, a town just nine miles outside of Pittsburgh. To be mindful of the areas history and our engagement with it, we will study the work of LaToya Ruby Frazier to understand the social and ecological effects of steel extraction, emission, and construction. Frazier builds a visual archive of the intersection of the steel industry, the environment, and the human body, describing her work as excavations of hidden histories, from the micro to macro level. Students are encouraged to collect data using photography, film, record sounds, 3D scanning, and taking drone footage of the site. The workflow will deploy generative adversarial neural networks, various 3D modeling, and rendering software. Students will produce a short animation for the final deliverable. The seminar welcomes students with little or no experience with computation and those with more experience.

48-622 Explorations in Craft: Soft Forms, Stable Structures

Fall and Spring: 9 units

This course focuses on physical model making of soft forms. Softness is an evocative quality in architecture, but how do we "find" and then represent those elusive soft forms? How do we demonstrate a level of intentionality and control in their execution outside the digital realm? How do we suspend disbelief and open haptic possibilities? How do we manipulate materials with control? Using soft materials and/or expressing fluid form we will explore analog and digital craft pairings for fabrication, assembly methods, and physical form-finding techniques. The design and use of items like cutting and sewing patterns, bending jigs and casting molds will introduce the types of interfaces that facilitate thoughtful crafting of models. While learning through making, students will develop their own expression of softness. Presentations, demonstrations, and workshops on craft will inform experiments focused on material qualities and their formal affordances. Explorations and experiments will also consider structural stability in relation to soft material and formal palettes. These will inform a final independent project. The methods we work with in this class are intended to open possibilities and refine model making skills. Note: The class will have a materials fee to cover workshop costs. There will be some teamwork.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)

48-625 Thesis Seminar

Fall: 9 units

This seminar is designed for students planning to work on a thesis project in the M.Arch program and is intended to prepare students for a semester long, studio-based thesis project in the following Spring. You will enter this course with a written thesis statement, a body of background research related to your topic(s), and an initial set of questions that can be interrogated by engaging in research and discussion. Your continued progress is supported by the collective engagement of the seminar participants and the structure provided by course assignments and deadlines, in addition to individual conversations and targeted feedback from the instructor. The seminar focuses on refining the scope of the thesis argument, defining the methods to make the topic(s) of inquiry actionable through design-based methods, and sharpening the communication about thesis work in all of its phases. Thesis work is highly self-directed and requires a level of metacognitive thinking, which includes identifying a valid area of concern motivating the work, understanding the disciplinary and societal context for the project, identifying the means and methods for acting, and establishing the criteria by which to evaluate the work. The course is structured around the individual effort required to advance these aims. In addition, it facilitates group conversation and the regular exchange of ideas, providing dialogue, feedback, and continued motivation.

48-630 M.Arch Studio: Praxis I

Fall: 18 units

TBA

Course Website: <https://soa.cmu.edu/march> (<https://soa.cmu.edu/march/>)**48-631 Fabricating Customization**

Fall

to be created by the department

Prerequisite: 48-205

48-634 Architectural Theory & Contemporary Issues

Fall

This graduate seminar explores important writings and ideas being discussed in architecture today in relation to "Design Ethics," one of the central pedagogies of the SoA and the M.Arch program. Theory is framed not primarily as design principle, but as a critical framing device to investigate the dominant forces and paradigms engaging architecture today, in the academy, the profession, and the community. Architecture is considered as both material technology and social agenda, a driver of inequality but also potentially a social justice machine, a high-tech, economic, ecological, and political change-agent. The focus is on current discourses, processes, and contexts rather than on the history of theory, or the latest buildings or architects. The seminar examines a different theme each week, with topics that vary annually to acknowledge the dynamic nature of the profession, environment, and global contexts. The work of the seminar will focus on readings, weekly presentations and discussions about the sources. For additional units, students may elect to do a research paper on a theoretical aspect of architecture that connects to the co-requisite course "Situating Research" and might lead to a thesis or grant proposal.

Course Website: <https://soa.cmu.edu/march> (<https://soa.cmu.edu/march/>)**48-635 Environment I: Climate & Energy**

Fall: 9 units

This course introduces architectural design responses for energy conservation, human comfort, and the site-specific dynamics of climate. Students will be expected to combine an understanding of the basic laws of comfort and heat flow with the variables of local climate to create energy design guidelines for their own work. The state of the art in building energy conservation and passive heating and cooling technologies will be presented, with take-home readings and assignments. To stress the significance of architectural design decision-making on energy consumption and comfort, full design specifications and calculations will be completed for a residential-scale building. Students will compile a professional energy consultant's report, designing the most viable energy conservation retrofit measures for their client from siting, massing, organization, enclosure detailing, opening control, to passive system integration and management. An overview of world energy consumption in buildings and energy design standards will be challenged by lectures on building energy conservation successes, and emerging demands for a broader definition of sustainability. The course will end with a focus on the design integration of natural conditioning systems and the potentially dynamic interface of mechanical systems in small- and large-scale buildings.

Course Website: <https://soa.cmu.edu/march> (<https://soa.cmu.edu/march/>)**48-636 Architecture & Agency**

Spring: 9 units

Coming Soon

48-637 Structures/Statics

Spring: 9 units

We examine structural types, structural behavior, material behavior, and construction constraints that underlie our design of buildings, emphasizing the need for a designer to envision a complete 3-D structure. We mostly build "orthogonal structures" constructed in horizontal and vertical planes, requiring high-strength modern materials such as steel or reinforced concrete, comprising roughly 75-80% of the course. This is complemented by "geometric structure" where the three-dimensional shape dictates function; prominent examples include membranes, cable nets, historic masonry domes, and shells. Geometric structure is characterized by "form-finding." Statics underlies all topics, and our treatment is consistent with NCARB expectations.

Course Website: <http://soa.cmu.edu>**48-638 Structures**

Fall and Spring: 9 units

This course examines structural types, structural behavior, material behavior, and construction constraints that underlie our design of buildings, emphasizing the need for a designer to envision a complete 3-D structure.

48-640 M.Arch Studio: Praxis II

Spring: 18 units

Architecture transforms and shapes relations between individuals, communities, objects and environments. Praxis II will continue to understand architecture as a modulator of complex cultural and historical flows, but will aim to do so by intensively exploring, evaluating, and expanding the role that tectonic cultures and their associated modes of architectural expression play in shaping our world. Through a non-linear, multi-scalar, iterative design process, small teams will develop and refine detailed architectural assemblies attuned to methods of construction, craft, and labor practices; to the role of structural configurations in organizing the spatial distribution of occupancies and human experiences; to how envelopes regulate and respond to thermal and visual performance while also participating in aesthetic discourse; to ecological synergies and impacts; to modes of participation in carbon culture, including environmental management systems, commuting culture, and other patterns of integration with urban context; and ultimately to the disciplinary imperative to integrate/orchestrate these multiple systems. Students will develop design skills while negotiating the complex issues of site, program, climate, aesthetics, and performance. Students will use a range of technologies, such as daylighting and radiation simulation, and Virtual Reality, for designing spaces that respect the natural environment and engage human perception.

Course Website: <http://soa.cmu.edu>**48-641 History of Modern Architecture**

Spring

This course investigates the global history of modern architecture and theory across the 20th century. We ask critical questions about the canon, the changing nature of history and theory, the biases embedded in terms like "modernism," "progress," and "Non-Western," and the deep legacies of colonialism, globalization, extractivism, and capitalism in which modern architecture so actively participated. After briefly identifying architecture's role in some of the great challenges facing the world today and #8212; climate change, high tech, and social justice and #8212; this course loosely works backward in time following these themes. Along the way we explore major movements of the Euro-American avant-garde and so-called "heroes" of modernism, but also diverse responses to modernity, including vernacular, popular, tropical, and even anti-architecture around the world. We will highlight the role of experimentation and provocation, but also of timeless ideals, local and indigenous traditions, and how they each intersect with the demands of function and technology as well as social and political imperatives. Work for the course falls into four categories: 1) attendance and participation in lectures and discussions; 2) reading, both original documents from the period, and more recent critical histories; 3) writing a series of 2pp. critical reflections on the readings; 4) a semester-long, carefully curated research project on "Non-Canonical" buildings from the Global South in the 20th-century.

Course Website: <http://soa.cmu.edu>

48-643 Color Constructs

Spring: 6 units

In this course you will study and experiment with the relationships and perception of space and form through two- and three-dimensional optical experiments using color. Lectures, discussions, and field trips will delve into color theory particularly focused on the work of artist, designer, and educator Joseph Albers, look at culturally defined use of color, and its experience. In keeping with Albers definition of color theory as a hands-on experiential and experimental process of creating relationships through perception students will work on skills needed to craft compelling images using linear, planar and volumetric assemblies in digital and analog media. Initial weekly exercises will cover principles of color relativity, intensity, temperature, etc., and consider various principles of graphic perception including but not limited to vibrating and vanishing boundaries, figure ground reversals, and the illusion of transparency. Through this process you will gain an understanding of the use of color in the graphic representation of designs, patterns, diagrams and architectural representations that will inform the use of color in transforming the perception of space. The final assignment will be a three-dimensional color structure.

48-644 M.Arch Pre-Thesis

Spring: 3 units

This 3 unit course is designed for B.Arch and M.Arch students a year before their final Spring semester. The course develops an understanding of research methods, and explores the formation of ideas for architecture thesis projects. Many directions of architectural thinking (spatial, material, ideological and procedural), will be discussed and in framing a theoretical position we will see how an architecture thesis can use a creative process to discover and express findings in relation to large questions and to disciplinary discussions. This is a required course for Fall Thesis Seminar in F23 (9units) and Spring Thesis ASOS 524 (18units).

Course Website: <http://soa.cmu.edu>**48-647 Materiality and Construction Systems**

Spring: 9 units

This course introduces students to contemporary methods of construction and draws attention to the materialization of architectural intent. It foregrounds the historical, technological, and conceptual basis of construction systems to understand the building as a process and cultural artifact. The course provides an overview of established and emerging construction systems to reveal how and why building processes are utilized. Materials and methods of construction are positioned as both constraints and affordances, each with distinct spatial, structural, environmental, economic, and aesthetic concerns. Through lectures, readings, and detailed analysis, students will learn about the construction of fundamental architectural conditions, including foundations, walls, frames, envelopes, and roofs. Production methods, spanning the vernacular to the digital will introduce cultures of building and design for manufacturing considerations.

Course Website: <http://soa.cmu.edu>**48-650 ASO Masters Studio**

Fall: 18 units

TBA

48-670 MArch Thesis

Spring: 18 units

Coming Soon.

48-676 Connected Communities: Technology, Publics, Politics, and Participation

Intermittent: 6 units

This seminar examines how smart and connected technologies can be designed for neighborhoods, what considerations are involved, and what effects such technologies create for communities. We will introduce and critically examine the relationships between smart systems with the places, infrastructures, histories, politics, publics and problems that surround them. To do this, we will survey topics across research and practice across different domains. These will reveal approaches, methods and design factors to designing systems for communities, as well as the challenges created when computing becomes a non-human participant in communities and publics. The first five weeks of this mini-course will introduce a series of topical readings, cases, guest lectures, case studies, and design exercises. The rest of the course will invite students to investigate topics and contexts of interest to them. By the end of the course, students will be familiar with the socio-technical considerations for designing systems for places and publics.

48-677 Hines Competition

Intermittent: 3 units

This course is for graduate students participating in the prestigious national Urban Land Institute (ULI) Hines competition. This is an intensive real estate and urban design competition that will take place January 9 - January 23rd. Optional pre-competition preparation workshop sessions will be offered the week prior to January 9th. The course itself includes delivering and sharing competition entries and completing a post-competition survey. The purpose of the competition and companion course is for cross-disciplinary teams of graduate students to work collaboratively to create a complex urban design and real estate proposal on a real site in North America. Competition entries include a narrative, drawings and financial analysis. Each team will select and work with a design faculty advisor(s). This course is typically required for Masters of Urban Design (MUD) students. Previous real estate course work or knowledge is preferred. All registrants will be wait-listed until their teams have been registered with ULI (deadline December 9th). Please contact the coordinator Valentina Vavasis to participate.

Course Website: <https://americas.uli.org/programs/awards-competitions/hines-student-design-competition/>**48-686 Systems, Cybernetics, Conversation**

Spring: 12 units

Across many design disciplines architecture and computational design, media and interaction design, design of services and organizations methods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

48-692 Shaping Daylight Through Simulation and Virtual Reality

Fall and Spring: 9 units

Light is one of the critical aspects of valued architectural spaces, influencing ambiance, the overall atmosphere, and occupant perception, whether positively or negatively. In this course, we will explore the quantities and qualities of light. We will study how we can design with and for light while understanding the paradox of lighting design that it is both science and art. Digital design and simulation tools will be augmented with virtual reality (VR) to extend quantitative measurements of lighting to include qualitative aspects of light such as its influence on occupants' subjective impressions of a space, wellbeing and comfort.

Course Website: <http://soa.cmu.edu>**48-699 Environmental Racism, Injustice, & Unfreedom: Lessons for Architecture**

All Semesters: 9 units

Environmental racism refers to the disproportionate concentration of environmental harms in low-income communities of color (particularly Black and indigenous communities) through the systematic workings both historic and ongoing of white privilege and white supremacy. More broadly, environmental injustices also include restrictions to environmental resources and infrastructures, and the unjust placements and displacements of communities of color resulting from uneven development. In this seminar we will examine the histories of environmental racism and injustice through close reading of literature from a range of fields including Environmental Justice, urban political ecology, Black geographies, and indigenous studies. We will ground our conceptual understandings through a closer look at ongoing environmental justice issues in Braddock and North Braddock, including through dialogue with local advocates and community members. Through the course of the semester students will develop a case study focusing on air pollution in the Mon Valley region, working collaboratively to produce an annotated bibliography of atmospheric pollution and community action.

Course Website: <https://soa.cmu.edu/courses#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-701 Entangled: Remaking Nature from the Picturesque to the Hypernatural

All Semesters: 9 units

This seminar questions how we perceive, represent, and reconstruct our world in relation to evolving concepts of "nature" and their manifestation in architecture, art, and landscape. It is focused on the intellectual trajectories that define ecology and environment to arrive at the paradigm shift theoretician Donna Haraway has termed natureculture. We will first familiarize ourselves with historical ways of seeing "nature" and how this has formed the landscapes of the Anthropocene. This will help us put a critical lens on land, environmental and ecological art, ecoventions, architectural living systems, biomimicry, biophilia, and projective ecologies while we consider the influence of gardens, responsive landscapes, hyper-natures, and artificial ecologies in changing the way we design and build. We look for not only relevance but joy and beauty in practices that highlight the relation between desire, responsibility, more-than-human wellbeing, and ecological justice. This may help us build notions of care and stewardship and an understanding traditional and emergent cultural constructs that can define an eco-centric practice which shapes building futures. The course surveys texts from a range of topics including ecological aesthetics, architecture, art, landscape urbanism, and ecologically focused philosophy and theory. It includes weekly readings, discussions, presentations, and visual or written deliverables. Open to graduate and undergraduate students in Architecture and allied fields.

48-706 Urban Design Studio II: Urban Systems

All Semesters: 18 units

Optimistic assessments about Pittsburgh's livability mask a complicated reality where prospects for health and well-being are starkly differentiated along lines of race, class, and gender. Environmental harms, underpinned by the ongoing legacies of industrial production, extraction, and segregative planning, create a toxic combination adversely impacting human health, ecology, and community futures. These challenges necessitate multidisciplinary, collaborative, and emancipatory approaches to knowing the built environment, and community-centered methods in urban design that attend to the local histories, embodied knowledges, and political ecologies of life in toxic systems. This studio will expand on MUD students' understanding of neighborhood-scaled urban design through the examination of urban systems and systemic processes, focusing on the infrastructures of toxicity, and modes of local action against them. It will be anchored in an ongoing collaboration with North Braddock Residents For Our Future, a grassroots organization which has led the opposition to unconventional gas drilling and environmental injustice in Braddock and North Braddock and surrounding communities.

Course Website: <http://soa.cmu.edu>**48-709 History and Future of Interaction Design**

All Semesters: 12 units

The history of Interaction Design is far richer than what is commonly known among students and teachers, practicing designers and entrepreneurs. Understanding IxD's origins and evolution helps us realize the promises and possibly avoid some of the pitfalls of IxD's future. This course blends readings, lectures, discussions, and prototyping as a means for students to experience this history as if first-hand. Students become immersed in pragmatic yet mind-expanding examples of person-machine interactions such as MEMEX, Musicolour, Hypertext, Dynabook, Fun Palace, Colloquy of Mobiles, Architecture Machine, THOUGHTSTICKER, Architrainer, and Hypercard. Through period articles and subsequent perspectives, students research a handful of historical innovations and then prototype key concepts from that history, forefronting what has been lost in modern commercial implementations. This offers students a hands-on experience of the history of IxD. To explore IxD's future, students are invited to invent to prototype their individual future vision of interactive experiences. The course is especially suitable for students with interest or background in interaction design, computational design, responsive architecture, and interactive media.

48-711 Paradigms of Research in Architecture

Spring

Architectural "research" by many practitioners is often limited to precedent studies and/or intuitively evaluating alternative design solutions and materials. Deeper analytical activities risk being perceived as unnecessary overhead expenditures. On the other hand, "architectural" research by many scholars is often confined to laboratory settings or so esoteric that the findings are of little use to practitioners. This course challenges the false dichotomy between these two frames and provides an introduction to a wide range of research strategies including Experimental, Simulation, Quantitative, Qualitative, Correlational, Interpretive-historical, Logical Argumentation, Case Study, and Mixed Methods. Throughout the semester there will be guest lectures from faculty who will share their expertise, successful research strategies and methods, innovative ideas for future research, and the results of their current and past research. Students will apply a variety of research paradigms and methods to their research interests, improve their verbal and visual presentation skills, and prepare a research proposal presentation with a problem statement, literature review, methodology/methods, anticipated findings, and bibliography.

Course Website: <http://soa.cmu.edu>**48-712 Graduate Seminar 2: Issue of Global Urbanization**

Intermittent

Abstract: By 2050 the number of urban dweller across the world will double. The seminar is an investigation into the future of cities focusing on three existential challenges: the escalating environmental crisis, growing social inequity and technological dislocation. In the face of these wicked problems, we will address the role and agency of designers and planners, decision makers and citizens in tackling what Jeremy Rifkin describes as the Third Industrial Revolution and how to lay the foundational infrastructure for an emerging collaborative age. These issues are explored through contemporary writings and case studies that situate urban transformations in the US within a broader global context, with a specific focus on the political as articulated through the negotiation of top-down planning and bottom-up behavior of cities. The seminar course will revolve around reading reflections, in-class presentations and student moderated discussions on theories and case studies of global urbanization. This is a 3- or 6-unit course that requires attendance at one 1.5-hours class per week. The extra credits involve a more extensive final paper. Students from diverse disciplines are welcome in this seminar. Key Topics: Global Urbanization, Uneven Growth, Political Economy, Ecological Urbanism, Resilience, Cosmopolitan Localism, Smart Cities, Commons. Course Relevance: An understanding of theories and practice of urbanism in global developments. Course Goals: The seminar provides an understanding of the social, political, economic and environmental forces at play in shaping our built environment and reflects on the role and agency of designers and planners can have in building more resilient and sustainable cities.

Course Website: <http://soa.cmu.edu>**48-713 MUD Urban Ecology**

Fall: 9 units

Urban ecology describes the complex relationships between humans and our environment and is bound by an understanding of system dynamics. Urban ecology draws from our understanding of urban settlements and the cultural values that shape them, as well as our conception of ecology as the resources and flows that support biotic systems. Urban ecology situates humans and our activities as part of a dynamic and living environment that is more continuum than a dichotomy. This class will examine the shifting regimes of urban ecology and equip students with skills and core concepts that enable them to lead or contribute to transition through design. As designers we are trained to see patterns and #8212;urban ecology asks us also to see processes and to speculate on effects and possible outcomes. This course will discuss the systems and the logics that create the patterns, and we will explore how our design process may be different when dealing with the ambiguity and uncertainty of systems design. We will learn the fundamentals of systems dynamics modeling as it applies to the design of historical and contemporary landscapes, infrastructure, and spatial practices at the macro-, meso-, and micro-scales.

Course Website: <http://soa.cmu.edu>**48-715 MSCD Pre-Thesis 1**

All Semesters: 6 units

This seminar introduces graduate students in Computational Design to the rudiments of graduate level academic research, and offers a space to discuss inchoate research methods, questions, and projects in the field. Assignments require students to gain familiarity with past and current research in the field in order to distinguish different research traditions, practices, opportunities and pitfalls. An emphasis is placed on the materialities and socio-technical infrastructures of computing.

Course Website: <http://SOA.cmu.edu>

48-716 MSCD Pre-thesis II

All Semesters: 6 units

With the notion of "critical technical practice" as a touchstone, this graduate-level seminar draws from across design, media, and science and technology studies to cultivate an awareness of the discursive and political dimensions of technology in design, and to guide participants in the formulation of a graduate thesis in computational design. Through readings, discussions, written assignments, and presentations participants develop the skills to identify and refine a research question, situate it within a wider scholarly conversation paying attention to ethical citational practices argue for its relevance, and creatively engage with conceptual and methodological research challenges. As a final deliverable, participants produce a thesis proposal and present it to faculty and students.

Course Website: <https://soa.cmu.edu/courses/#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-720 Planning by Design: Campuses, Waterfronts, Districts, and Cities

Spring

In responding unprecedented challenges of density, information, equity, and climate change, cities continue to define and design "districts." Waterfront, historic, arts, innovation and ecodistricts draw on models including on university/corporate campuses, neighborhoods, main streets, and downtowns. How can cities remake districts in that are viable in terms of engagement and opportunity? How can they be meaningful and inclusive in a society that appears to be increasingly less place-based? Through presentations, case studies, and the semester project, students will develop strategies to respond to these challenges.

Course Website: <http://soa.cmu.edu>

48-721 Building Controls and Diagnostics

Intermittent: 12 units

The course will introduce students to collecting and processing data acquired from building systems and evaluating their performance. It will discuss the basics about control systems, including both traditional control logics, like rule-based control and model predictive control, and advanced control logics like reinforcement learning based control. Proficiency in Python and maturity in mathematics is required. Knowledge of website design and reinforcement learning is recommended.

Course Website: <http://soa.cmu.edu>

48-722 Building Performance Modeling

Fall

This graduate-level course examines the emergence of computation as a pivotal concept in contemporary architecture and design through a selection of design theories and practices responding to the so-called "computer revolution". An aim of the course is to explore computation beyond particular technologies and tools, and to cultivate an awareness of design technologies as cultural artifacts shaping disciplinary identities and worldviews, and shifting conceptions of design, creativity, nature, body, and place. The semester is divided into two-week thematic modules, often with computational design faculty participating as guests covering topics derived from their own research. Each module includes readings and a short team-based project expanding on the topic introduced. Topics include among others shape grammars, tangible interaction, responsive environments, cybernetics, and architectural robotics. The course also introduces participants to the rudiments of academic research, in particular to the elements and structure of an effective research paper. Participants practice reading and responding to both historical documents and contemporary research related to each topic, and develop a critical understanding of a rapidly expanding landscape of hybrid practices, theories, and research methods linked to computational and interactive forms of creative practice.

Course Website: <https://soa.cmu.edu/courses/#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-723 Performance of Advanced Building Systems

Spring

Advanced Building Systems Integration This is a graduate level course that focuses on commercial building performance achieved through systems integration. In lectures, class discussion, and student projects, we will explore the topic of building performance, the design and technical strategies that support sustainable high performance; the design, construction and operation processes that are likely to produce sustainable high(er) performance buildings; and the current state of theory versus practice. The course assumes a basic understanding of buildings' impact on the environment, of building design and materials performance, and the calculation of building heating and cooling loads. On that foundation, we will examine the concept of systems integration and how this approach can sustain the occupants and the environment far better than conventional design, construction and operation. Although US climate, building conventions and codes will be our reference point, we will broaden our discussion by using examples and data from many other countries. An essential aspect of our exploration will be identifying successful built projects and examining the factors that may have allowed those projects to succeed. If this course meets its objectives, students who successfully complete the material will understand and be able to discuss sustainable building performance characteristics, will understand the systems integration approach and how it differs from conventional approaches to building design, and will know how to positively affect architectural and engineering decisions to support the design, construction and operation of sustainable high performance buildings.

48-724 Scripting and Parametric Design

Intermittent: 10 units

This course prepares students for modeling geometry through scripted development of parametric schemes primarily for design applications that is, to introduce students to basic scripting in geometrical modeling environment with a focus on algorithms relating to form making and to reinforce and extend basic concepts of parametric modeling. Contemporary approaches to modeling geometry are computational reflected in designers wanting much more control over the generative process by varying parameters, in turn, enhancing the efficiency with which they navigate design variations, analyze design artifacts and explore design manifestations. This course has two parts: firstly, to supply the basics of object-oriented programming and algorithmic thinking using Python language constructs, and secondly, to supply the basics of scripting generative form making specifically, by customizing procedures for generative design via scripts in GhPython in conjunction with Rhino/Grasshopper objects. A number of different form-making algorithms are explored, e.g., fractals, rule-based models, cellular models, agent-based models, and optimization-based models. The course consists of lectures, computer instruction and weekly assignments. Prior exposure to Rhino/Grasshopper is required.

48-725 Graduate Real Estate Development

Fall

This course teaches the fundamentals of real estate development in the U.S. You will learn about the real estate development process and the social, economic and regulatory context in which land use and real estate development take place. We will learn about project team members and processes; market research; site constraints and zoning; basic project budgeting and types of funding sources. We will also discuss social equity issues related to land use, including affordable housing, racial segregation and economic inequality. This course typically includes international students which allows us to learn from each other and compare real estate and land use issues in various countries. The primary objective of this course is for students to understand how these issues might affect their professional and personal lives, whether they become designers, contractors, engineers, public policy professionals or real estate developers. The course includes learning terminology, reading current news articles, and completing a team project, sometimes with a Pittsburgh-based client. Students will have the first two weeks of class to select nine or 12 credits; 12 credit students will complete additional work. Open to graduate students from any school including SoA, Tepper and Heinz Undergraduates with instructor permission only

Course Website: <https://soa.cmu.edu/courses/#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-729 Sustainability, Health and Productivity to Accelerate a Quality Built Environment

Intermittent

Given the United Nations Sustainable Development Goals and the growing demand for sustainable design by federal and private sector clients, professional practices are "tooling up" all over the world to deliver high performance and environmentally responsible buildings, infrastructures and communities. However, investments in 'green', high performance building solutions and technologies are still limited by first cost decision-making, and life cycle tools are still largely inaccessible to professionals. This course explores the relationship of quality buildings, building systems, infrastructures and land-use to productivity, health, well-being and a sustainable environment. The course begins with a series of lectures on high performance enclosure, mechanical, lighting, interior and networked building design decisions and extends to sustainable communities and infrastructures. The course engages students in the research literature that relates these building design decisions to multiple cost/performance impacts, including: energy, carbon, facilities management, organizational change, technological change, attraction/retention (quality of life) of employees, individual productivity, organizational productivity, salvage and waste (the circular economy), tax/ insurance/ litigation, and human health.

Course Website: <https://soa.cmu.edu/courses#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-731 Sustainable Design Synthesis Prep

Spring

TBD

Course Website: <https://soa.cmu.edu/courses#graduate> (<https://soa.cmu.edu/courses/#graduate>)

48-733 Environmental Performance Simulation

Intermittent

"Design of a boat is optimized for sail-driven locomotion. Buildings should be able to sail using free energy if wind, air, sun and internal heat sources to temper indoor environment", Brendon Lewitt. Based on this viewpoint, this course introduces fundamental knowledge in building physics in relation to a range of environmentally responsive building design principles and computational approaches for increased resiliency for human habitability with minimal reliance on mechanical systems. EPS course refreshes some of the fundamental building physics topics such as building thermodynamics (heat and amp; mass transfer mechanisms), photometric quantification of light and luminous environment, human visual and thermal comfort, thermal modeling and the principles of generating electricity from sunlight (photoelectric effect). EPS course outlines a series of environmental design principles with emphasis on evidence-based design approaches and reviews of building case studies are evaluated against actual buildings in operation. Focus is also given to integration of multi-valent environmental design strategies into the early stages of performative architectures. EPS also introduces state-of-the-art architectural design and amp; research oriented environmental performance simulation and amp; visualization tools, methods and techniques (based on the algorithmic/parametric modeling ecosystem of RHINO-Grasshopper-DIVA-ArchSIM -Ladybug-Honeybee programs). Computational introductions will be accompanied with pre-established/seed workflows which are ready for future adaptation and extension by the students.

48-737 Detailing Architecture

All Semesters: 9 units

This course examines the role of the architectural detail in the formation/ thematic development of a work of architecture and how the detail reinforces the theoretical position of the architect. Architectural detailing is often considered only a technical task, but in fact the detail holds the key to inspire, integrate and reinforce the architectural idea as well as the architect's intellectual/ societal position. Many scholars, historians and academics have avoided the detail as a snapshot into the design methodology of architecture. This class is an attempt to do the opposite. The course will consist of a series of weekly lectures, readings, field trips and student developed graphic and physical representations that reveal how the role of detail has played an essential role in the history, evolution and development of the built environment.

Course Website: <http://soa.cmu.edu>

48-738 Special Topics: Ecological Footprints

Fall: 6 units

The Ecological Footprint is a measure of the demand that human activity puts on the biosphere. More precisely, it measures the amount of biologically productive land and water area required to produce all the resources an individual, population, or activity consumes, and to absorb the waste they generate, given prevailing technology and resource management practices (Global Footprint Network 2010). This course will engage students in the metrics and impacts of our collective consumption and waste of: -Energy -Materials (Cradle to Cradle) -Food -Water -Transportation -The Integration of Systems towards Quality of Life Starting at the global context, this course will address challenges/opportunities to advance regenerative practices, improving our relationship to nature. Learning from international best practices, we will continue to explore ecological footprints at the global, national, regional, city, neighborhood, building and individual scale. The course will be based on lectures and readings, with assignments and student presentations to fully explore each of the footprint characteristics. Experts on water, energy, materials, food and other resources have been invited to lecture. By mid semester, an application project will be selected for ecological footprint analysis and the development of design, engineering, and operational guidelines towards reducing that footprint. The potential application projects include: the CMU campus footprint and Donner House retrofit; the Energy Innovation Center and education of the trades in reducing our regions footprint; or a new Net Zero building for Carnegie Mellon University. This will be a collaborative effort.

Prerequisite: 48-305

48-739 Making Things Interactive (Graduate)

Fall: 12 units

In this hands-on design-build class you will learn the skills to embed sensors and actuators (light, sound, touch, motion, etc.) into everyday things (and places etc.) and to program their interactive behavior using a microcontroller. You'll also dive into the fields of VR/AR/MR and experiment with combining these disciplines with physical computing. Through weekly exercises and a term project the class will introduce basic analog electronics, microcontroller programming, projection mapping and virtual reality; as well as exploration into using kinetics and materials to make the things you design perform. Emphasis will be on creating innovative experiences. The graduate edition of this course will require additional work including a paper that can be submitted to a peer-reviewed interaction design conference such as CHI, UIST, or TEI. Students from all disciplines are welcome: but please note that the class demands that you master technical material. Experience in at least one of: programming, electronics, or physical fabrication is strongly recommended.(Participants will provide their own supplies and materials.)

48-743 Introduction to Ecological Design Thinking

Intermittent: 9 units

This seminar offers an overview of scholarly, design-based and research-based approaches to issues of ecology and sustainability in architecture and urban design. The seminar intends to question contemporary paradigms of sustainability within the built environment and includes inquiries from different disciplinary perspectives ranging from history, theory, technology, engineering, art and design. The goal of this seminar is to offer a platform for critical thinking, in-depth discussion and analysis of actionable methodologies related to sustainability, and procedures relevant to the shaping of our physical environment and social systems. Composed of a series of lectures, readings and short assignments, this seminar will lead students through a diverse collection of interdisciplinary views and positions towards defining what is our understating of sustainability today, and what is a role of large scale ecology within the constructed environments. Students will be introduced to a wide overview of technical, analytical, practical, theoretical and intellectual inquiries that will help them to navigate varied fields of expertise and enable their future investigation of innovative sustainable strategies for the built environment. This seminar will consist of majority of lecture sessions and 2 project review sessions, spread across the fall semester. Each session will introduce set of readings and/or a small exercises related to the lecture theme. The invited lecturers come from both: academia and practice. Invited speakers' areas of research and design work feature diverse approaches to issues of sustainability and technology. This seminar serves as a platform for development of a cross-disciplinary theoretical foundation to investigate varied methodologies towards sustainable design practice.

48-745 Design Fabrication

Fall and Spring: 9 units

Design Fabrication is a project based seminar exploring the application of Computer Aided Manufacturing (CAM) in architecture. The course meets in the School of Architecture's Design Fabrication Lab (dFAB), which serves as a context to better understand the interconnected affordances of building materials, machine processes, and modeling software for design thinking. During the semester students receive hands-on introductions to dFAB equipment, including laser cutting, cnc routing, and 3D printing. Concepts will be explored and tested through iterative making/prototyping. Course Focus The course focuses on Transdimensional Fabrication, a manufacturing framework that forefronts design thinking across space and time. A growing array of approaches in contemporary architecture are motivated by this focus (e.g. flat pack, 4D printing, metamaterials, kinetic architecture, robotic origami, design for disassembly, etc.). We will investigate Transdimensional Fabrication concepts through three that forefront design translations: 2D 3D, Space Time, Assembly Reconfiguration Disassembly

Course Website: <http://soa.cmu.edu>**48-746 Shape Machine**

Fall: 9 units

A shape machine is any computational technology that fundamentally expresses the way shapes are represented, indexed, queried and manipulated. In this course the shape machine is based on visual rules (shape rules) grounded in symbolic rules (programming language instructions) to provide a robust technology to individuals who use drawings and visual models to develop and communicate their ideas. A shape machine is intended to be a computational, visual and disruptive technology for shape cognition and computing, which intersects with such fields as design, artificial intelligence, computer science, and mathematics. We consider a particular kind of shape machine - spatial grammars - which have their origin in formal grammars for spatial composition. Grammatical approaches to designing offer an alternative to traditional approaches. The goal of grammars is not to produce a single design as the final outcome, but, rather, to provide an understanding of the underlying spatial relations that come into play in an eventual design. For nearly three decades, grammars have been studied extensively to understand style in architecture, engineering, design, fine art and ornament. Recently, there has been an increasing application of grammatical ideas to other disciplines. Specifically, there is resurgent interest in implementing shape grammars for application. This is the focus of this course.

Prerequisite: 48-724

48-749 Special Topics in Computational Design

Intermittent: 6 units

This project-based course interrogates the confluence of robotics and artificial intelligence methods and its potential applications to design, manufacturing, and construction domains. In combination with a group of computational design and robotics faculty and PhD students, course participants will advance visions for the future of design that do not aspire to full automation, but instead at culturally-situated, algorithmically and robotically-supported cooperative processes. Course participants will be able to take advantage of new laboratory space and state-of-the-art equipment at CMU's new Mill 19 facility, and help envision, develop, and evaluate functional prototypes for robotically-supported design and construction.

48-750 Histories of Urban Design

Fall: 9 units

This architectural and urban design history course examines the cultural histories of the design and redesign of world cities. The scale of urban interventions we will look at varies greatly, from the macro-scale of designing totally new capitals to the micro-scale of altering small nodes within a city. We explore the relationship between form and culture by considering political, social, economic, and aesthetic forces that have shaped the public realm of urban as well as suburban spaces. We focus on recognizing and understanding the rationale behind the design, re-design, and use of culturally important urban spaces during their own time, making periodic forays into the issues that influence those spaces today. Non-majors are welcome.

Course Website: <https://soa.cmu.edu/courses> (<https://soa.cmu.edu/courses/>)**48-752 Zero Energy Housing**

Fall: 9 units

Are you interested in designing or renovating the high-performance multifamily housing of the future? Would it surprise you to know that despite numerous successful single-family projects, only a limited number of successful multistory, multifamily zero examples exist? Creating multifamily housing that reaches net zero or carbon neutral goals is challenging since occupant behavior can influence the outcome as much as building design and construction. Yet multifamily housing is an essential typology to address rapid development and urbanization. Take on the challenge of creating high performance housing for our net zero future by exploring the technical and social demands of multifamily zero energy design or renovation. 48-752 is a graduate level course designed to support that goal. Through lectures, outside research, discussion, and a final applied project, you'll explore the design approaches, codes, policy, technology, and energy infrastructure options that can help you achieve the housing performance we know is essential for a sustainable future.

Course Website: <http://soa.cmu.edu>**48-753 Intro to Urban Design Media**

Fall: 6 units

The methods and media used to represent the urban environment are essential tools for documenting existing conditions, proposing new interventions, illustrating suppressed or hidden characteristics, and communicating ideas to fellow practitioners as well as the broader public. The successful communication of Urban Design thinking relies not only on the quality of the subject but also on the caliber of the media used to represent it. This course explores new forms of media and representation in Urban Design. The seminar is a project-based course consisting of bi-weekly exercises and reading assignments. Students will adopt their own hometown as the primary site for their analysis and representation. Throughout the semester, students are tasked with identifying a specific subject unique to their site of inquiry. They will then analyze, interpret and re-represent their subject through a variety of media, including collages, maps, images, renders, matrices, and animated GIFs, and AI-generated imagery. Consideration will be given to drawing/image quality, technique and aesthetics.

48-755 Introduction to Architectural Robotics

Fall: 9 units

This course provides a practical, hands-on introduction to the application of industrial robotics in architectural and related construction domains. It also provides students with the necessary knowledge and safety protocols to work in the architectural robotics lab at CMU SoA. Through lectures, labs, and project work you will learn the industrial robotic fundamentals of on-line programming, off-line programming, simulation, end-of-arm-tool (EOT) development, workcell development, and interacting with peripheral sensors. This course is a prerequisite for more advanced engagement with the lab equipment through SoA courses, student thesis projects, and research. No prior knowledge of industrial robotics is required to succeed in the course. Students should have basic knowledge of Rhinoceros 3D modeling and visual scripting in Grasshopper. Prior programming experience is recommended, but not required. All students should exhibit careful attention to lab safety policies and the determination to test ideas through physical making and iteration.

Course Website: <https://soa.cmu.edu/courses#graduate> (<https://soa.cmu.edu/courses/#graduate>)**48-756 Project Planning and Reporting**

Fall

The goal of this course is to expose the class to advanced project scheduling methods and familiarize the students with the primary reporting practices as performed in the construction industry such as change management, resource charts, and project status reports. The course objectives are as follows: 1. Outline and discuss the established practical approaches of planning and reporting; 2. Demonstrate the dynamic nature of construction projects stemming from inherent uncertainties. 3. Hone a student's adaptability to the dynamism of the process while delivering construction projects. This course will include both discussions on assigned topics and a studio-based collaborative group project. In order to provide a real-world experience to the students the second half of the semester will feature a group project focused on tracking a construction project with varying situational scenarios such as changes in resources and scope creep. Throughout the semester there will be one midterm and intermittent homework with the final deliverable being a "close out" document, which would essentially be a compilation of all the work during the semester projects.

Course Website: <http://soa.cmu.edu>

48-758 Responsive Mobile Environments (Grad)

Intermittent: 12 units

As part of this project-based course, we'll get hands-on with emerging technologies, concepts and applications in the Internet of Things through a critical lens. We'll prototype everyday intelligences and design smart and connected devices that examine and speculate on the strange, supernatural, and mystic qualities of the smart home. The first half of the semester will introduce students to building connected devices and intelligent spaces through technical development workshops, readings, applied explorations, and guest lectures. The second half of the semester will be organized as an applied collaborative project.

Course Website: <http://rme2021.daraghbyrne.me>**48-759 Value Based Design Introduction**

All Semesters

This course will explore the fundamentals of project values, incentives and motivations as they relate to the diverse, sometimes conflicting perspectives of a project's stakeholders. It will hone the student's understanding of multifaceted issues required in problem seeking and stakeholder collaboration to make a design project successfully relevant in the business world and society. Students will learn proven methodologies in documenting and incorporating value into the ethos of the project delivery team's thinking from design concept to construction completion. The class will rely on case studies and interviews with clients, architects and contractors to advance the idea of balancing the principles of Return on Investment (ROI) with Return on Design (ROD). Key Topics: The course will cover the critical role of design thinking in the decision making process of developing the built environment. The semester will examine not only the types of Value Based Design but learn methods to elevate and preserve Design Value from inception through construction. After developing an understanding of stakeholder value and the role that design holds in its creation the students will be given opportunities to identify examples of the various types of Value Based Design. Everyone will share their discoveries with the class and defend their reasoning behind each examples.

Course Website: <https://soa.cmu.edu/>**48-763 Protean Systems: Sustainable Solutions for Uncertain Futures**

Intermittent

Uncertainty perpetually plagues the built environment. The inability of our buildings and cities to adapt to shifting circumstances has led to an enormous amount of waste. We will explore various forces and scales of change and review various strategies (Spatial Flexibility, Metabolism, Shearing Layers of Change, Open Building, Design for Deconstruction (DFD), Circular Economy, Dynamic Facades, Smart Materials, Transformable Structures, Resiliency, Persistence, and Adaptive Reuse) through a wide array of built precedents and products that have attempted with varying degrees of success to respond to these forces over time. Throughout the semester students will individually and collectively reflect on the readings and work in teams to prepare case studies representative of each strategy. Students will also iteratively redesign a project of their own choosing that applies the strategies through sketches, diagrams, animations, and models or complete a detailed individual case study that includes archival documents, interviews, facility assessments, and other evidence of how the project has changed over time. The course welcomes students from all SoA and SoD undergraduate and graduate programs.

Course Website: <https://soa.cmu.edu/courses#graduate> (<https://soa.cmu.edu/courses/#graduate>)**48-770 Introduction to Machine Learning in Design**

Spring

With the recent blooming of artificial intelligence (AI) and machine learning (ML) came a renewed interest in how these technologies may impact architecture and other creative practices. Introduction to Machine Learning in Design introduces students to this emerging field, giving them the tools to make their own machine-learning-based design tools by adapting state-of-the-art models, developing new models, and understanding how data shapes machine learning algorithms. Throughout this course, students explore two main fields of machine learning and their potentials in design and making problems: Unsupervised Generative Models, Natural Language Processing. Students will be introduced to the fundamental concepts of each field and get hands-on experience with state-of-the-art research and tools to implement them. Prospective students should have strong Python programming skills. Prior basic familiarity with Machine Learning is a plus. Taking Fundamentals of Programming (15-112) or school of architecture courses such as Design + Computation 1 or Scripting and Parametric Design before taking this course is strongly recommended but not mandatory.

Course Website: <http://soa.cmu.edu>**48-779 Processes of Digital Design Fabrication**

Intermittent: 3 units

Digital Fabrication techniques are well established and widely used across all stages of design to production. Contemporary pre-occupations with materiality, ornament, digital craft, and surface topology are tethered to the affordances of these workflows and their direct connection to digital design methods. The impact of these processes reverberates across scales and around the globe, its presence undeniable. Off-site, prefabrication techniques are increasingly reliant upon computational methods to achieve greater control and precision, while recasting traditional design to production workflows. The architects traditional conveyor of design intent, the working drawing, and its conventions of plan and section are increasingly supplemented with machine and robot code. Meanwhile the jobsite and field construction of buildings remains a largely human endeavor, reliant upon the skill of local labor to assemble the many components that constitute a building to produce the one-off piece of architecture. This tension between the promise of the factory floor and the messy reality of the job site reflects the evolving nature of construction and its regimes of labor. Building construction is an industry in flux rooted in traditions that pre-date the emergence of computation, yet also in the midst of digital disruption as seen in advancements in onsite architectural robotic fabrication. Left they succumb to greater marginalization, architects must engage these transformations and leverage their design affordances. Practitioners should be versed in the basic principles of digital fabrication and understand its affordances and potential influence upon the design process. Translations from drawing and model to building increasingly rely upon these modes of production. Emerging practitioners must be capable of engaging these modes of communication and leveraging these techniques in the realization of their design intent.

48-780 MAAD Design Research Project Prep

Spring: 3 units

TBD

48-781 Spatial Analysis in Infrastructure Planning

Spring: 12 units

A Geographic Information System (GIS) provides storage, retrieval, visualization, and analysis of geographically referenced data. GIS provides analytical tools to investigate spatial relationships, patterns, and processes of location-based data such as cultural, demographic, economic, environmental, health, physical, social, and other phenomena. GIS creates digital twins (virtual representations) of natural and built environments and integrates many types of digital models. GIS topics include geographic concepts (projections and map scales), map design, geodatabases (importing spatial and attribute data, geocodes, table joins, and data aggregation), spatial data processing, digitizing, data mining, multivariate cluster analysis, drive and walk time networking, raster GIS, spatial statistics (proximity and hot spot analysis), animation, and 3D GIS. CAFM (Computer Aided Facility Management) and IWMS (Integrated Work Management Systems) topics include space and asset management, building operations, environmental health and safety, and real property. The course includes in-person and asynchronous video lectures to learn important GIS concepts and a brief introduction to work management systems. Software tutorials cover leading GIS software from Esri Inc. Applications include ArcGIS Pro, ArcGIS Online, ArcGIS Map Viewer, ArcGIS Story Maps, and Dashboards. Subject areas are related to architecture, engineering, construction management, building performance, environmental health, sustainability, public policy, urban design, and planning.

Course Website: <http://soa.cmu.edu>**48-783 Generative Modeling (GRAD)**

Fall and Spring: 9 units

This course introduces students to the fundamentals of generative modeling using computer aided design as practiced in the field of architecture. Core competencies will be developed through modeling projects and software intensive labs, while a broader critical framework for conceiving of contemporary and historical parametric practices will be encouraged through periodic lectures. Emphasis will be placed on careful consideration of digital mediums and developing a sense of craft related to digital modeling in the hope that students will become conscientious makers and consumers of digital content. Students will be encouraged to understand and apply algorithmic problem solving to the many design constraints encountered in architecture. The course will explore the relationship of parametric workflows to design thinking and will situate contemporary trends in a broader framework of computational design. The course will also forefront complex form-making as a response to bio-mimicry, systems thinking, and mass-customization. Rather than positioning parametric modeling as a disruption of historical architectural design process, the course will encourage students to consider how new tools might augment the discipline's historical commitments to orthographic projection, perspectival drawing, and physical modeling.

48-786 PORTFOLIO & RESUME PREPARATION (G)

Fall and Spring: 3 units

Portfolio is a unique document that showcases your professional and academic journey through various media and interfaces. Portfolio's capacity to represent a body of work and as a storytelling tool is emphasized in this course. The course proposes a fresh way of thinking about portfolio types and their content. Portfolio is a document through which you invite an audience to explore mediums of your creative thinking, forms of imagination, sense of materiality and possibilities of shaping the real conditions. The course deals with curating the content, editing your portfolio, resume, cover letters and work sample design. We shall look at myriad drawing types, layouts, typefaces and get into technicality of workflow, project sequence and details of the portfolio. In each session we shall select a particular content of the portfolio and discuss through presentations, diagrams, key references and students and amp;#39; work. Each project has its prompt, is unique in terms of its scale, modes of investigation and tools of representation. A successful portfolio shows diverse tools of thinking and communication.

48-788 Proseminar in Computational Design

Fall: 6 units

No course description provided.

48-795 LEED

Spring: 6 units

If you're interested in sustainable infrastructure and community design, have you considered how "green" strategies may vary around the world? Are there universal goals for the design of sustainable transportation, water systems or energy infrastructure, or must green goals and design approaches be adapted to a national or local context? 48795 A4, LEED, Green Infrastructure and Community Rating in Global Context, is a graduate level mini-course that compares global community and infrastructure rating systems to gain perspective about sustainable infrastructure development and community design. The course uses two rating systems and #8212;the US Green Building Council's Leadership in Energy and Environmental Design (LEED) Cities and amp; Communities Rating System and the Institute for Sustainable Infrastructure (ISI) Envision Rating System as springboards for exploration and discussion of other world rating systems that address these topics. We'll consider how the goals and implementation of a rating system may reflect the national context in which the system was created and discuss emerging issues that may be omitted from these rating systems. The course provides a foundation for taking USGBC's LEED Green Associate and/or LEED Accredited Professional exams, or the ISI Envision Sustainability Professional exam and is designed to hone your critical thinking about sustainable urban design and infrastructure development in a global context.

Prerequisite: 48-315

Course Website: <http://soa.cmu.edu>**48-801 Office Visits**

Fall: 6 units

Each candidate will arrange with their home office a virtual 'visit' for members of the degree program and organize presentations of the projects, methodological challenges, recurring problems, best and worst practices within the context of their office experience. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-802 Principles of Research I

Fall: 6 units

Candidate's current knowledge of problems, methods and outcomes based on their professional work. Overview of the eight knowledge areas as existing disciplines and their potential place in them. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-803 Areas of Practice

Fall: 6 units

Candidate presentations of area(s) of expertise summarizing the methods and problems that are prevalent; using case studies to establish a situated approach to research. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-804 International Exchange I

Fall: 12 units

Conduct workshops for collaborative research and information exchange meetings with EU cohorts visiting from the Universit and #233; Toulouse III - Paul Sabatier, Doctoral Programs in Architecture. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-805 Directed Study I

Fall: 6 units

Prepare the first publishable article under the supervision of the advisor, based on the current professional practice record of the candidate. Submitted to a committee of faculty for approval. Asynchronous Course Delivery (Fall 2014) - and gt; September 18, through December 7, 2014 Online Synchronous Course Conclusion (Fall 2014) - December 8-11, 2014

48-809 International Exchange II

Spring: 12 units

Visit Universit and #233; Toulouse III - Paul Sabatier, Doctoral Programs in Architecture and participate in collaborative research and information exchange meetings with EU cohorts, based on the cohorts current knowledge base culled from their practice experience. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015 and #8212; Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

48-810 Comparative Analysis of US and EU Practices

Spring: 6 units

Practices in the building sector vary considerably in the US versus the EU. The instructor will provide a rich collection of national and international initiatives in the AEC domains and include a stimulating series of site visits to important installations in the area. Asynchronous Course Delivery (Spring 2015) - January 18, through May 13, 2015 and #8212; Online Synchronous Course Conclusion (Spring 2015) - May 14 through 17, 2015

School of Art

Charlie White, Head
Location: College of Fine Arts 300
www.art.cmu.edu/ (<http://www.art.cmu.edu/>)

The School of Art's undergraduate program bridges traditional studio practice with the experimental practices of new and unconventional media. The School offers two tracks for undergraduates—the Bachelor of Fine Arts (BFA) degree and the four interdisciplinary degrees collectively known as the BXA Intercollege Degree Program—along with a minor in art.

The program provides focused foundational instruction over the first year that builds toward a broad range of individualized study in the following three years. In their first year, students experience a wide array of intensive medium-specific studio courses, developing both technical skill and critical thinking. Following the completion of their foundation year, students direct their study across four primary concentrations with the freedom to pursue either in-depth study, hybrid study across concentrations, or specialized practices. Throughout the entire curriculum, the program emphasizes a conceptual approach to artmaking, challenging students to expand their ideas of artmaking and reconsider art's possibilities.

The four primary concentrations are:

- I. Drawing, Painting, Print Media, and Photography
- II. Sculpture, Installation, and Site Work
- III. Electronic and Time-Based Work
- IV. Contextual Practice

Studio courses comprise over sixty percent of the course of study and academic courses comprise the remainder.

The School of Art occupies over 50,000 square feet of fabrication facilities, multi-purpose classrooms, media-specific studios and workshops, student and faculty studios, presentation rooms, and exhibition spaces, offering students access to both traditional and state-of-the-art tools. All juniors and seniors have dedicated, independent, 24-hour studio space.

The School's distinguished faculty includes pioneers in computer animation and new media; artists and scholars exploring the complexity of queer thought and culture; and emerging practitioners confronting some of society's most pressing issues. Throughout the program, these professors provide one-on-one support and feedback, helping each student foster an individualized artistic practice.

The program emphasizes an interdisciplinary approach to learning and art making, and students are encouraged to take advantage of the many resources of the College of Fine Arts and of the University. These include: the IDEATe network, the STUDIO for Creative Inquiry, the Miller Institute for Contemporary Art, and the Center for Arts in Society, among many others.

Graduates from the School of Art pursue diverse careers paths including traditional studio practice, animation, game design, positions with leading technology companies, and founding their own start-ups.

Using five categories of courses, the curriculum presents art-making in a unique manner which respects tradition and encourages innovation. The course categories are:

- I. Foundation Courses
- II. Intermediate Studios
- III. Advanced Studios
- IV. Critical Studies Courses
- V. University Academic Courses

I. Foundation Courses

In their first year of study, students take a total of six foundation studio courses, exploring a range of mediums and conceptual processes. These studios ensure that all students have an exploratory experience with all of the media resources of the school. They also serve as preparation for intermediate and advanced studio work.

In addition, the Art First-Year Seminar introduces you to facilities, faculty, staff, resources, and many opportunities you can access within Art and the broader university. All first-year students take the seminar together, allowing you build a strong community that will help you develop as an artist during your time at CMU and beyond.

II. Intermediate Studios

Students take a minimum of six Intermediate Studio courses of their choosing in preparation for Advanced Studios in their junior and senior years. Intermediate studios will build on foundational knowledge and allow students to direct their studies to those mediums and topics most strongly of interest.

III. Advanced Studios

Students take a minimum of six Advanced Studio elective courses in their junior and senior years. These courses address specialized studio work in one of the four artistic concentration areas in the school, which are:

- Drawing, Painting, Print Media, and Photography (DP3)
- Sculpture, Installation, and Site Work (SIS)
- Electronic and Time-Based Work (ETB)
- Contextual Practice (CP)

In addition, students complete another six studio courses, which can be either Intermediate or Advanced Studios. This allows for significant exploration and integration across mediums within the program.

A minimum of four courses must be taken in one of these concentration areas. One of the intermediate or advanced courses can be a studio-based course within the College of Fine Arts, IDEATe, or additional programs.

IV. Critical Studies Courses

Students are introduced to critical studies in the spring of their first year, taking Foundations: Critical Studies. After the first year, students take four elective critical studies courses to broaden their knowledge and inform their studio practice. Critical Studies courses are discussion-based seminars examining theoretical texts in relation to periods of artistic practice. Readings will introduce students to the historical and critical background of the themes discussed in class and familiarize them with the varied methodologies and argumentative styles proper to art criticism, critical theory and philosophy.

V. University Academic Courses

Ten academic courses outside of Art and Computing @ Carnegie Mellon are required.

First Year

In the first year of study the student is expected to complete the following three requirements:

- Computing @ Carnegie Mellon (99-101)
- One First-Year Writing option
- One Global/Cultural Studies elective

For First-Year Writing, the student selects one of the two full-semester courses, (Interpretation and Argument (76-101) or Advanced First Year Writing: Special Topics (76-102)), or two of the three half-semester writing courses (Writing about Literature, Art and Culture (76-106), Writing about Data (76-107), or Writing about Public Problems (76-108)).

The Global/Cultural Studies electives include but are not limited to the following courses:

| | | |
|--------|--|---|
| 57-173 | Survey of Western Music History | 9 |
| 57-306 | World Music | 9 |
| 57-480 | History of Black American Music | 6 |
| 76-333 | Race and Controversy in the Arts | 9 |
| 76-337 | Intersectional Feminism | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 76-221 | Books You Should Have Read By Now | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 79-145 | Genocide and Weapons of Mass Destruction | 9 |
| 79-201 | Introduction to Anthropology | 9 |

| | | |
|--------|---|---|
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-234 | Technology and Society | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-345 | Roots of Rock & Roll | 9 |
| 79-350 | Early Christianity | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 80-100 | Introduction to Philosophy | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 82-xxx | Any Modern Languages course | |

After First Year

The student must take one course in each of the following academic areas or "options":

- Humanities and Languages or "Culture Option"
- Math, Science, Computer Science and Engineering or "Technical Option"
- History, Psychology, Economics or "Social Science Option"

The student must then take at least three additional courses from one of the academic areas/options listed above.

Finally, the student must take two additional, but unspecified, academic electives.

In selecting courses for the university academic component of the curriculum, students are encouraged to complete a cluster of courses that appeals to and develops their interests as emerging artists. In the process of taking their university electives, students can often simultaneously earn a minor.

Bachelor of Fine Arts (B.F.A.) Curriculum

Minimum units required for B.F.A. in Art 384

Below is the recommended distribution of courses in the four-year B.F.A. curriculum. After the freshman year, students may begin to choose university electives. After the first semester of the sophomore year, students have more options regarding the sequencing and selection of their coursework.

First Year

| Fall | | Units |
|--------|-------------------------------------|-----------|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 76-10X | First-Year Writing | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| | | 48 |

| Spring | | Units |
|--------|----------------------------------|-----------|
| 60-107 | Foundations: Critical Studies | 9 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-135 | Foundations: Sculpture II | 10 |
| 60-170 | Foundations: Paint/Print | 10 |
| xx-xxx | Cultural/Global Studies elective | 9 |
| | | 48 |

Second Year

| Fall | | Units |
|--------|------------------------------|-----------|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-3xx | Critical Studies Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |

| Spring | | Units |
|--------|------------------------------|-----------|
| 60-200 | Sophomore Review | 0 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-3xx | Critical Studies Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |

Third Year

| Fall | | Units |
|--------|--|-----------|
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-3xx | Academic Art Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |

| Spring | | Units |
|--------|--|-----------|
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-xxx | Intermediate or Advanced Studio Elective | 10 |
| 60-3xx | Academic Art Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |

Fourth Year

| | | Units |
|--------|--------------------------|-----------|
| Fall | | |
| 60-401 | Senior Studio | 10 |
| 60-4xx | Advanced Studio Elective | 10 |
| 60-4xx | Advanced Studio Elective | 10 |
| xx-xxx | Academic Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |
| Spring | | |
| 60-402 | Senior Studio | 10 |
| 60-4xx | Advanced Studio Elective | 10 |
| 60-4xx | Advanced Studio Elective | 10 |
| xx-xxx | Academic Elective | 9 |
| xx-xxx | Academic Elective | 9 |
| | | 48 |

Sophomore Reviews

Students give an overview of their work at the midpoint of their four-year course of study. At the end of the sophomore year, students undergo a faculty review of their work to date in the program.

Art Majors Minor or Double Majoring in Another Department

About a third of current B.F.A. Art students pursue a minor or a second major. If students are contemplating this option, they must discuss their plans with academic advisors from the minor or second major department as well as with the School of Art academic advisor.

Study Abroad

Art students are encouraged to spend either a semester of their junior year, or a summer before or after their junior year, in one of many available international programs. These programs include university sponsored and exchange programs in which a student's financial aid package remains in effect, and programs sponsored by other institutions.

Programs with other Pittsburgh Institutions

Art students are eligible to take courses at the nearby University of Pittsburgh's History of Art and Architecture Department, and at the Pittsburgh Glass Center. Established agreements with these institutions and other Pittsburgh colleges, universities or centers offer cross-registration opportunities at no additional expense to the student.

BXA Intercollege Degree Programs

BACHELOR OF COMPUTER SCIENCE AND ARTS (BCSA)

BACHELOR OF ENGINEERING STUDIES AND ARTS (BESA)

BACHELOR OF HUMANITIES AND ARTS (BHA)

BACHELOR OF SCIENCE AND ARTS (BSA)

Carnegie Mellon University offers a degree program that combines an Art Focus (12 courses) with a focus in the College of Engineering, the School of Computer Science, the Dietrich College of Humanities and Social Sciences, or the Mellon College of Science. The Assistant Head of Academic Affairs in the School of Art advises BXA majors in selecting courses in the Art Focus. A description of these three programs, and a list of requirements and electives, can be found in the in the BXA Intercollege Degrees Program section (p.) of this catalog.

Art Minors

Students from other colleges and departments are eligible to pursue a minor in art. A minor requires six courses in the School of Art, selected from a list of requirements and electives as described in the Minors Offered by the College of Fine Arts section (p. 188) of this catalog.

Master of Fine Arts (M.F.A.) Degree

The School of Art offers a three-year program leading to a Master of Fine Arts in Art. This is a unique program designed to connect art-making to the university at large, and to Pittsburgh communities and organizations. Information about this program is available at the School of Art website (<http://www.art.cmu.edu/mfa/overview/>).

Master of Arts Management (M.A.M.) Degree

The College of Fine Arts and the Heinz College School of Public Policy and Management co-sponsor a Master of Arts Management degree. Students admitted to the M.A.M. degree program in their junior year may complete both a Bachelor of Fine Arts degree and a Master of Arts Management degree in five years. Students interested in this graduate degree should consult with advisors early in their undergraduate program.

Pre-College Program

The School of Art offers a Summer Pre-College Program, with both three- and six-week options. This program is designed to prepare the college-bound high school student for college level work in art. Information is available at the Summer Pre-College site (<https://www.cmu.edu/pre-college/>).

Full-Time Tenure Track Faculty

LYNDON BARROIS JR., Assistant Professor of Art – MFA, Washington University in St. Louis; Carnegie Mellon, 2020–

KIM BECK, Associate Professor of Art – M.F.A., Rhode Island School of Design; Carnegie Mellon, 2004–

ELIZABETH CHODOS, Assistant Professor of Curatorial Practice, Director of Miller Institute of Contemporary Art – M.A., School of the Art Institute of Chicago; Carnegie Mellon, 2017–

JOHANNES DEYOUNG, Assistant Professor of Art – M.F.A., Cranbrook Academy of Art; Carnegie Mellon, 2018–

JAMES DUESING, Professor of Art – M.F.A., University of Cincinnati; Carnegie Mellon, 1997–

ISLA HANSEN, Assistant Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2019–

RANEE HENDERSON, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2023–

KATHERINE HUBBARD, Assistant Professor of Art – M.F.A., Bard College; Carnegie Mellon, 2019–

ANDREW JOHNSON, Associate Professor of Art – M.F.A., Carnegie Mellon University; Carnegie Mellon, 2004–

JONGWOO JEREMY KIM, Associate Professor of Art History and Theory – Ph.D., Institute of Fine Arts at New York University; Carnegie Mellon, 2018–

LING-LIN KU, Assistant Professor of Art – M.F.A., University of Texas at Austin; Carnegie Mellon, 2022–

GOLAN LEVIN, Professor of Art – M.S., Massachusetts Institute of Technology; Carnegie Mellon, 2004–

CLAYTON MERRELL, Dorothy L. Stubnitz Professor of Art – M.F.A., Yale University; Carnegie Mellon, 1998–

PAOLO PEDERCINI, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2009–

RICHARD PELL, Associate Professor of Art – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2008–

MELISSA RAGONA, Associate Professor of Visual Culture and Critical Theory – Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2003–

BRITT RANSOM, Associate Professor of Art – M.F.A., University of Illinois at Chicago; Carnegie Mellon, 2022–

SHARMISTHA RAY, Assistant Professor of Art – MS/MFA, Pratt Institute; Carnegie Mellon, 2023–

JON RUBIN, Professor of Art – M.F.A., California College of Arts and Crafts; Carnegie Mellon, 2006–

SUZIE SILVER, Professor of Art – M.F.A., The School of the Art Institute of Chicago; Carnegie Mellon, 1999–

ANGELA WASHKO, Associate Professor of Art – M.F.A., University of California, San Diego; Carnegie Mellon, 2015–

CHARLIE WHITE, Regina & Marlin Miller Head, Professor of Art – M.F.A., Art Center College of Design; Carnegie Mellon, 2016–

IMIN YEH, Assistant Professor of Art, Director of Foundational Studies – M.F.A., California College of the Arts; Carnegie Mellon, 2016–

Full-time Joint Appointments

CHARLEE BRODSKY, Associate Professor of Art and Photography – M.F.A., Yale University; Carnegie Mellon, 1978–

ROGER DANNENBERG, Senior Research Computer Scientist and Artist – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1982–

JAMIE GRUZSKA, Special Faculty and CFA Photography Administrator – M.F.A., University of Buffalo;

DYLAN VITONE, Associate Professor, School of Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2006–

Visiting Faculty

MARIA ELENA VERSARI, Visiting Professor of Art History and Theory – Ph.D., Scuola Normale Superiore;

ALISHA WORMLEY, Visiting Core Faculty, MFA – M.F.A., Bard College; Carnegie Mellon, 2018–

Research and Teaching Faculty

YOKO SEKINO-BOVÉ, Assistant Teaching Professor of Art – M.F.A., University of Oklahoma; Carnegie Mellon, 2023–

School of Art Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

60-104 Foundations: Art First-Year Seminar

Fall: 6 units

Foundations: First-Year Seminar is a critical aspect of beginning your experience as a School of Art Student. This course introduces you to the school's many facilities, equipment, opportunities, staff, and faculty that will be essential resources for you throughout your four years at CMU School of Art. You will build community with your entire first year cohort, both BFA and BXA students, as you share 24 hour access to the Foundations Studio, a multi-use shared studio space that will support your studio coursework during your first year. Through lectures and panel discussions, you will explore various methods of artistic research and forms of making that support today's creative citizens. Through hands-on demonstrations, you will learn technical skills and gain access to equipment that will prepare you for academic and artistic success at CMU and beyond.

60-105 Cultural History of the Visual Arts

Spring: 9 units

Have you ever felt that you liked an artwork but couldn't explain why? Do you have questions about art that you were always afraid to ask? This course is conceived to give students the tools to feel at home when visiting a museum and talk about art in social, business and academic settings. It is organized over two semesters, but students can take only one of the two courses. Cultural History of the Visual Arts I (in the fall) covers the period from the 1500s to the 1800s and features masterpieces and lesser known works in Western and Non-Western art, organized chronologically and by theme. Some of the topics we will study include the controversy surrounding Leonardo's and Michelangelo's works, the role of censorship in the arts, the development of perspective experiments and visual theories from Antiquity onward, the concept of landscape and the status of the artist in the Ming dynasty, the impact of colonialism and post-colonial identity in South American Art, the rediscovery of Pompeii and Herculaneum and the Egyptian craze in the 1800s, the world of Opera and ballet, and the Impressionists' ideas of what an artwork should be. The course also includes museum visits that will be organized taking in consideration the students' schedule. No prerequisite required and open to students from all disciplines.

60-106 Cultural History of the Visual Arts - the Modern Period

Spring: 9 units

Have you ever felt that you liked an artwork but couldn't explain why? Do you have questions about art that you were always afraid to ask? This course is conceived to give students the tools to feel at home when visiting a museum and to talk about art in social, business and academic settings. It is organized over two semesters, but students can take only one of the two courses, or both, in any order they prefer. Cultural History of the Visual Arts -The Modern Period (offered in the spring) covers the period from the 1800s to the 2000s and features masterpieces and lesser-known works that define our idea of what art is and what role it has in society. Some of the topics we will study include the invention of a "modern" ways of seeing in Japanese art; the impact of science, film and photography on the Impressionists; the myth of the artist as a savage, a fool, and a prophet; the creation of ideal homes for common (and uncommon) people; the meaning of the avant-garde; and the many ways in which artists and politicians experiment with art and architecture in order to control our minds and emotions. The course also includes museum visits that will be organized in relation to the students' schedules. No prerequisite required and open to students from all disciplines.

60-107 Foundations: Critical Studies

All Semesters: 9 units

Foundations: Critical Studies is a seminar course that expands your historical knowledge concerning contemporary art and human experience in society. Through critical reading and writing, you will learn how the role of artistic research contextualizes the conceptual creativity of your studio practice. This course involves close reading and discussions of a wide range of texts, from foundational theory to short stories, nonfiction, poetry, exhibition reviews, artist interviews, curatorial essays, and excerpts from scholarly monographs. Today's visual artist will find that writing is a key to future professional opportunities and that research, writing, and theory are integral parts of artmaking. This course integrates analytical reading and research-based writing into your creative process.

60-110 Foundations: Time-Based Media

Spring: 10 units

Foundations: Time Based Media introduces you to audio and video production software, equipment and techniques into your interdisciplinary studies in art. Projects explore the making and critiquing of moving-image and audio across a variety of contexts, and takes an active approach in learning how to produce your own new media work using both standard and experimental production techniques. You will build comprehension of related histories and theories; explore the meanings and consequences of ubiquitous broadcast and social media; and learn how to interrogate and wield media paradigms to challenge their influences in our lives.

60-120 Foundations: Digital Media

Spring: 10 units

Foundations: Digital Media is a practical introduction to expanded modes of creative practice made possible by the computer. In this studio course, you will develop the skills and confidence necessary to produce interactive, generative, and immersive artworks; discuss your work in relation to current and historic praxes of electronic art; and engage new technologies critically. Topics will include no-code and low-code approaches to: internet art, immersive world-building, and environmental storytelling; generative art and experimentation with learning machines; creative interventions and performance in social platforms; and the development of branching narratives and games.

60-125 IDeATe: Introduction to 3D Animation Pipeline

Fall and Spring: 12 units

This class will explore computer animation as it pertains to a professional animation production pipeline. The course is designed to give students exposure to key job descriptions that align to the animation industry. Topics covered include: character design, world building, storyboarding, digital sculpture, look development, rigging, layout, animation, cinematography, lighting, and rendering. These topics are taught in 2-4 week sprints that allow a student to learn the fundamentals of each craft. In a mixture of class lectures, critiques, and training workshops, students will become acquainted with the necessary skills needed to create their own characters and animations. By completion of the course, students will be familiar with industry-standard best practices and ready to take advanced courses related to animation, vfx, and video game related pipelines. This course specifically offers insight on how the craft of animation is always evolving at top studios such as Walt Disney Animation Studios, Pixar, and Industrial Light and Magic.

Course Website: <http://cmuanimation.weebly.com/>

60-126 Introduction to Performance Capture and Rendering

Intermittent: 6 units

[IDeATe course] This mini is designed for those interested in the growing world of performance capture and visual effects. Utilizing the advanced motion capture facilities at Carnegie Mellon and the Kinect, students will learn how to capture motion from performance and apply it to CG characters and objects. While this technique is found in many video games and vfx movies, it has the ability to create endless possibilities within the realm of computer graphics and experimental animation/art. Students will also become more familiar with the process of rendering to create the necessary polish for their animations/visualizations. CG Lighting, camera work, and material shading are just a few of the many topics covered in this course.

Prerequisites: 15-104 Min. grade C or 62-150 Min. grade C

60-128 IDEATe: Real-Time Animation

Fall: 10 units

An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-131 Foundations: Sculpture

Fall: 10 units

Foundations: Sculpture I is an introductory studio course in concepts, techniques, and tools for the fabrication of three dimensional physical works. The studio course introduces both digital and physical fabrication methods to translate ideas and materials into 3D forms. We will cover measuring, drawing, planning, pattern making, and construction techniques for cardboard, fabric, recycled materials, and a variety of mixed media; as well as the use of plaster, paper clay, and / or wax. Through technical demonstrations, assignments, and hands-on explorations, students will learn how to make use of equipment in our sculpture labs such as laser cutters, sewing machines, and a variety of hand tools. Concepts explored as a group include physical and sensorial properties such as scale, weight, and materiality; as well as deconstruction / disassembly, reconstruction / reassembly, transformation, translation, function, dysfunction, and utility. Our experiments will prompt us to consider relationships between objects, bodies, spaces, and society; as well as between technology, craft, form, and language; ultimately exploring how to use the making of 3D objects as both a communicative tool and a practical tool for life. No prior knowledge or experience in the field is required to take this course.

60-135 Foundations: Sculpture II

Spring: 10 units

Foundations: Sculpture II is an introductory studio course in concepts, techniques, and tools for the fabrication of three dimensional sculptural works in wood and metal. This studio course introduces physical fabrication methods to translate ideas and materials into 3D forms. We will cover measuring, drawing, planning, subtractive and additive processes, joinery techniques for wood and metal, and a variety of materials in combination with these construction techniques. Through technical demonstrations, assignments, and safe hands-on explorations, students will learn how to use equipment located in our woodshop and metal shop, including major saws and sanders, hand tools, metal saws, and MIG welders. This class will explore concepts and histories related to functional object-making and utility; as well as sculpture in relation to space and site. Through presentations, readings, and class dialogue, students will be introduced to contemporary artists working across 3D physical media and installation, with special attention to the relationship between idea and materiality. Our experiments will prompt us to consider relationships between objects as architectures, bodies, spaces, and society; as well as between technology, craft, and language; ultimately exploring how to use the making of 3D forms as a communicative tool. No prior knowledge or experience in the field is required to take this course.

60-136 Ceramics for Non-Majors

Intermittent: 10 units

An introduction to three-dimensional form in clay, with access to our ceramics facility and kiln firings. Skills covered include hand building, sketching and modeling for larger fireable clay forms, throwing on the wheel, and basic glazing techniques. Discussions will include contemporary artists working in ceramics, as well as historical examples, and various approaches and techniques for working in clay.

60-137 Physical Computing for Non-Majors

Intermittent: 10 units

TBA

60-141 Black and White Photography I

Fall and Spring: 10 units

This course will teach you the basic craft of photography from exposure of the negative through darkroom developing and printing to print finishing and presentation. Content includes student presentations, class discussions, shooting assignments, darkroom sessions and class critiques. We will concentrate not only on the technical aspects of photography, but also the aesthetics of seeing with a camera. The course concentrates on photography as a fine art and #8212; what is unique to it and the concerns that are shared with other visual arts, such as composition, tonal values, etc. and aims to equip students with an understanding of the formal issues and the expressive potentials of the medium. Lab fee and 35mm manual camera required. Each student is responsible for the cost of paper and film.

60-142 Digital Photography I

Fall and Spring: 10 units

This course explores digital photography and digital printing methods. By semester's end students will have knowledge of contemporary trends in photography, construction (and deconstruction) of photographic meaning, aesthetic choices, and the use of color. Students will learn how digital cameras work, proper digital workflow, RAW file handling, color management and Adobe Photoshop. Through the combination of the practical and theoretical, students will better define their individual voices as photographers. No prerequisites.

60-150 Foundations: Drawing

Fall: 10 units

Foundations: Drawing is a vital foundation for your interdisciplinary studies in art. This course will concentrate on the traditional elements of drawing and design: structure, line, shape, texture, motif, gesture, value and composition. You will be introduced to figure drawing, portraiture, perspective, and media experimentation. By the end of the semester, you will understand the importance of drawing as a visual language as well as a means of thinking. You will be expected to expand your mindset of what constitutes drawing and apply skills, knowledge and ideas from other studio classes and academic studies to your work.

60-170 Foundations: Paint/Print

Spring: 10 units

Foundations: Paint/Print introduces you to color, paint, printed multiples, and digital imaging to expand upon the techniques, concepts and materials used in contemporary two dimensional image making. You will work predominantly in drawing and painting (water based media), but will also have opportunities to experiment with screen printing, risograph, image transfers, and digital output. With an emphasis on material exploration, you will investigate how scale, medium, and color support or distract from the intention of your artwork. You will think about how contemporary artists do visual research in our image and media saturated world, and what it means to appropriate, collage, produce memes, and/or publish in multiple media. Working in multiples and in series, you will practice working iteratively, producing deeper visual exploration of your artistic concept and intention.

60-200 Sophomore Review

Fall and Spring

Students present their work and their ideas about their work to a faculty committee. A successful review is required for advancement to the junior year. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA, and BCSA) sophomores.

60-201 Intermediate Studio: Social Practice

Fall: 10 units

In recent years, socially-engaged art projects that invite exchange, imagine new social relationships, and provoke individual and collective action have gained increasing prominence. These projects can double as a barter network, a walking tour, a residency program, a protest, or even a post-natural history museum. Rather than being the result of a solitary artist working within an isolated studio, social practice projects are driven by the desire to connect, to look outside oneself in meaningful and tangible ways, and to impact daily life within specific communities. Through the production of work that intersects with a variety of publics, students in this class will use their art practice as a means for directly engaging with the world around them.

60-203 Publics

Intermittent: 10 units

Publics, introduces students to the wide range of approaches artists use to engage with different audiences, contexts and publics. Publics acknowledges that all artwork exists within specific social and political conditions and embraces that context as a fundamental material of art-making. In this course, students will be asked to consider what artists' roles and responsibilities could be - culturally, politically, and socially. Throughout this course, students will be introduced to interdisciplinary cultural practices which seek to critique, challenge and alter public systems and ultimately create artworks which explore power dynamics, subjectivity, institutional frameworks, accessibility and more. Through the production of art engaging with a variety of publics, real and virtual, students will explore the possibility of becoming active change agents in the world through making. Students will respond to theory-driven prompts and are encouraged to take risks and explore a variety of different approaches to art-making, as each assignment will not have a specific medium requirement.

60-204 Futures

Intermittent: 10 units

In Futures, students will be asked the question, "what if?" Looking backwards and forwards students will grapple with what futures might be possible, impossible, desirable, undesirable and more. Throughout the class, students will explore critical and imaginative world-making and utopian, dystopian, and ambiguous scenarios from a variety of perspectives through the act of making. In addition to speculating and inventing futures, students will explore various histories of the future - through mythologies, origin stories, science fiction, futurist movements across cultural contexts, and more. Students will respond to theory-driven prompts and are encouraged to take risks and explore a variety of different approaches to art-making, as each assignment will not have a specific medium requirement.

60-208 Alternative Photography: Contemporary Antiquarian Printmaking

Intermittent: 5 units

This course will explore alternative photographic techniques and concepts in an effort to extend the boundaries of the photographic image. Through the course we will investigate contemporary digital imaging techniques and apply them to turn-of-the-last-century hand-applied emulsions. Subjects covered are digital imaging, digital negative printing and workflow, hand-applied emulsions, alternative uses of Polaroid photography, and concepts and theory of the still image. As we move through the course we will also consider the theory and history of photography and create images that are not standard in today's imaging practices. A diverse range of contemporary photographic work will be presented to increase students' visual awareness and understanding of the possibilities inherent in the medium. Through work/review sessions, students will evaluate their own ideas and judgments in pursuit of a well-communicated image.

60-212 Intermediate Studio: Creative Coding

Intermittent: 12 units

This is an intermediate level course in "creative coding": the use of programming and computation within the context of the arts. Ideal as a second course for students who have already had one semester of elementary programming (in any language), this course is for you if you'd like to use code to create art and #8212; AND you're already familiar with the basics of programming, such as for() loops, if() statements, objects, and arrays. Students will develop or deepen the skills and confidence to produce interactive, generative, and computational artworks; discuss their work in relation to current and historic praxes of computer art; and engage new technologies critically. Through rigorous programming exercises, students will develop mastery over the basic vocabulary of constructs that govern static, dynamic, and interactive form, with the aim of applying these skills to problems in creative explorations of transmediality, connectivity, generativity, and immersivity.

60-213 Intermediate Game Studio: Real Time 3D

Intermittent: 10 units

Game Studio: Real Time 3D is a hands-on intermediate course focused on immersive environments, world building, character creation, and real time experiences at the boundaries of gaming. On a conceptual level we'll look at practices within digital art and independent game development: virtual architecture and sculpture, walking simulators, avatar-based performances, and other playable media. On a technical level the course will introduce you to 3D modeling for real time applications (using Blender) and game engine workflows (using Unity) as a scaffolding for advanced courses. Students will work individually. Experience with game engines and 3D modeling is not required.

60-214 Photography and the Narrative of Place

Intermittent: 5 units

This half-semester course will use photography to develop understandings of our surrounding environments. Students will choose a single location to work in, photographing and researching its function in the community, its history, and its relationship to broader concepts and similar spaces. Weekly assignments will require students to work with a variety of photographic methods to construct a narrative that derives meaning from the complex connections between people, objects and the spaces they inhabit. Throughout the course, students will strengthen their understanding of the ways in which these tangible and abstract elements of our environments work together through in-class exercises, weekly discussions and critiques. The course work will culminate in a portfolio of the completed project. The class will study work and books by notable and emerging figures in the medium, including Robert Adams, Carolyn Drake, Roy DeCarava, Rinko Kawauchi, Alec Soth, Carrie Mae Weems, Zoe Strauss, Gregory Halpern, and Susan Lipper. Required readings will include essays and short stories by Wendell Berry, Rebecca Solnit, Teju Cole, Joan Didion, and Georges Perec.

60-216 Intermediate Studio: Story Development for Animation

Intermittent: 10 units

This intermediate studio explores story and character development for animation. Animation is a rich and diverse field of creative inquiry - one that affords unique and expressive possibilities for communication across a wide spectrum of media. Contemporary animation is not limited to cinematic modes of storytelling, but abides across expanded forms, such as non-linear, spatial, and real-time interactive media. This course explores a variety of storytelling strategies through coursework that builds proficiency in: story structures and narrative; storyboarding; legible character posing and layout design principles; expressive cinematography, staging, and lighting; and effective timing, spacing, and editing techniques. A combination of rigorous studio practice, historical exposition, and theoretical discourse will equip students with the practical techniques and critical tools required to advance new dimensions in animated storytelling. Studio work emphasizes hands-on making through a variety of materials, exercises, and independent projects. Students will be exposed to a variety of perspectives and techniques, including outlooks and practices from both studio-industry and independent artists. Class discussion will consider affordances availed across a wide and diverse spectrum of creative and professional paths, expanding awareness and exposing new possibilities for storytellers in the Twenty-first Century.

60-217 Intermediate Studio: Experimental Hybrid Film - Video and Animation

Intermittent: 10 units

Digital production and post-production technologies have made hybrid moving images that combine live action, animation and image processing ubiquitous. Collage processes and aesthetics are at work even in moving image media that appear naturalistic. While developing proficiency in Adobe After Effects and other production and post production tools, students in this course will explore the experimental world-building and storytelling possibilities of hybrid moving image production. The course is structured around technical tutorials and workshops, readings and screenings, and the creation of collaborative and independent hybrid filmmaking exercises and projects. Artists whose work we will look to for inspiration include Yuge Zhou, Shana Moulton, Tabita Rezaire, Rachel MacLean, Chitra Ganesh, Jee Young Lee, Sondra Perry, Miwa Matreyek, Saya Woolfalk, Jacobly Satterwhite, Alex DaCorte, Grace Nayoon Rhee, Nam June Paik, Wangechi Mutu, Joo Young Choi, Cecile B. Evans, Ryan Trecartin, Oskar Fischinger, Karel Zeman, Sin Wai Kin, Winston Hacking, Russ Murphy (RUFFMERCY), Jordan Belson and many others.

60-218 IDeATe Portal: Real-Time Animation

Fall: 10 units

An introductory course that explores improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in motion capture technologies, real-time 3D computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of video art, animation, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.

60-220 IDeATe: Technical Character Animation

Fall: 10 units

Technical Character Animation is a deep dive into the fundamental concepts of character animation and "The Illusion of Life." This course will focus on building a foundation of body mechanics that demonstrate weight, balance, and authenticity. Through a series of strategically designed modules, students will gain a command of the 12 principles of animation, beginning with a ball bounce to more advanced block, spline, and polish workflows. This course is designed to give students exposure to the art of movement as it is done by animators in the fx, film, and game industries.

Course Website: <http://tcacmu.weebly.com/>**60-222 Intermediate Studio: Animation**

All Semesters: 10 units

This is an open animation studio for students who want to improve existing animation skills and develop a personal animated short. The class will introduce a variety of techniques and concepts for animation production. Using both 2D and 3D tools, animation will be explored through short assignments designed to develop diverse skills and ideas. Each student will develop and produce a short animation. The class will engage in discussion and critique of each other's work along with examples of historic and contemporary animation.

60-223 IDEATe Portal: Introduction to Physical Computing

Fall and Spring: 10 units

This practical project-based course covers the basic technical skills (including electronics, programming, and hardware) needed to build simple interactive objects with embedded behavior using the Arduino microcontroller. A sequence of projects challenge students to apply their technical skills in creative ways. For the final project, the class works with a local group of older people who serve as design clients; students conjure and build them functioning custom interactive assistive devices of a practical or whimsical nature. Sensor inputs covered include an ultrasonic ranger, thermometer, light sensor, and human inputs like buttons and knobs; outputs to affect the world include actuators such as motors, LED lights, speakers, and haptic feedback devices. This introductory portal course has no technical prerequisites. Readings and guest speakers address topics including design, disability, and aging. See courses.ideate.cmu.edu/60-223/s2018/work for examples of prior student projects. Contact rzach@cmu.edu with any questions about the course. Students are encouraged to also take the micro course 99-353 IDEATe CAD and Laser Cutting.

Course Website: <https://courses.ideate.cmu.edu/60-223> (<https://courses.ideate.cmu.edu/60-223/>)

60-232 Intermediate Studio: Interactive Objects

All Semesters: 10 units

Interactive Objects is an intermediate sculpture course that explores the concepts, techniques, and tools behind making interactive, responsive, or kinetic art works using physical computing and basic robotics. This studio course introduces students to building circuits, programming with arduino and processing, and integrating human-computer and human-object interaction into sculptures and installations. Through technical demonstrations, assignments, and hands-on explorations, students will build circuits, experiment with various sensors and actuators, program microcontrollers, re-wire existing electronics, and better understand electrical current and conductivity in order to harness it to create responsive elements and motion. Students in this course will be given priority access to the tools and equipment in our physical computing lab, as well as learn how to integrate these tools with our other digital fabrication facilities, including laser cutters and 3D printers, as well as our soft sculpture lab. Students will be expected to do technical assignments as well as individually-motivated self-driven projects based on research and ideas they find personally interesting and compelling. Our research, experiments, and projects will prompt us to consider the relationship between the digital and the physical; as well as the relationships between objects, bodies, technologies, spaces, cultures, and societies. No prior knowledge or experience in the field is required to take this course.

60-234 Intermediate Studio: Ceramics

All Semesters: 10 units

This course is a comprehensive introduction to the craft of ceramic art. Students will investigate clay as an art material for personal expression. The primary emphasis is on studio work leading to a portfolio of finished pieces by the end of the semester. The goal of this course is that students will be able to create expressive, three-dimensional clay forms with the proper understanding of the materials and process. The topics include, but are not limited to, various construction techniques such as soft and hard slab, pinch, coil, and wheel-throwing. Also, surface treatment techniques such as texturing and underglaze painting will be introduced. Discussions will include contemporary artists working in ceramics as well as historical examples and various approaches and techniques for working in clay. This course will consist of demonstrations and lectures, research/writing assignments in and out of class, as well as work time. Students will develop a body of work within the context of the projects to express their individual voice. This course requires students to participate in critiques to analyze their own and others work and identify strengths and weaknesses while promoting artistic growth and the exchange of ideas. No prior experience in clay is required.

60-236 Intermediate Studio: Mixed Media

All Semesters: 10 units

How Do Things Connect? Even when a sculpture may appear to be made with a single material there are often complex connections between many elements that are intended to either be visible or invisible. How do physical connections between materials and objects affect our visual experience? Can the ways pieces connect create or reinforce meaning in an object? Might you need to invent your own forms of joinery for a sculpture? This class focuses on a variety of contemporary approaches to making mixed media sculpture with an emphasis on how things connect both physically and conceptually. Students will learn a wide range of techniques for assembling dissimilar materials including hot and cold metal joints, wood joinery, adhesives and kinetic and flexible joints. Basic metal fabrication and intermediate wood constructing techniques will be developed on an as needed basis to accommodate individual projects and inquiries. Through in-class practice, assignments, research, presentations, readings, and critiques students will take on self-directed projects that explore how things connect in a deep and meaningful way. The goal for this course is to develop a stronger understanding of materials in order to broaden your options when considering how you choose to put your sculptures together. Connections between parts are just one more aspect of developing your own personal visual language. It is recommended that a foundations sculpture course be completed as a prerequisite for this class.

60-240 Unfolding Environments: The Intersection of Person and Place

Intermittent: 10 units

In this course students will use photography to develop projects that study our social environments and personal landscapes. This studio explores the ways photography can combine form and concept to derive meaning from place. Students will be assigned two projects for the semester. The first will be a brief study of a familiar space. The second will comprise the remainder of the semester, concentrating on a single location of the student's choosing. Students will photograph and research their chosen place's function, its history, and its relationship to broader concepts and comparative spaces. A series of prompts, readings, lectures, and critiques will help students build their project and develop new ways to approach their subject matter as they create a long-form narrative.

60-241 Black and White Photography II

Fall and Spring: 10 units

Black and White Photography II continues developing your technical skills in analog photography by introducing medium and large format cameras and prints. Large format view cameras remain the state of the art in control and quality in both film and digital photography. These cameras as well as unusual panoramic and pinhole cameras will be supplied. This course emphasizes aesthetic development and personal artistic growth through individual tutorials and group critiques, and will help to build professional level photography skills. Additional topics include digital printing and negative scanning, advanced monotone printing methods, and a focus on exhibition and folio presentation. Prerequisites: 60-141 or 62-141

60-242 Digital Photography II

Intermittent: 10 units

Digital Photography II combines digital and analog processes in both color and black and amp; white. Students will gain experience with digital workflow, analog to digital conversion, virtual drum scanning and large format digital printing. Topics include trends in contemporary photography, professional practices, project development, narrative and serial work, and portfolio presentation. Students will be expected to develop their own self-directed projects throughout the semester culminating in a cohesive portfolio of their work. Readings, assignments, artist visits, critiques and discussions will give context to the practical work and help develop a wide ranging familiarity with the subjects. Prerequisites: 62-141 or 60-142 or 60-141 or 62-142

60-244 Contemporary Photo Theory

Intermittent: 9 units

Because, you know, the photographs are more a question than a reply. (Sebastiao Salgado) A photograph is a moral decision taken in one eighth of a second, or one sixteenth, or one one-hundred-and-twenty-eighth. (Salman Rushdie) This seminar investigates current topics in photography and the image; our goals are twofold: identification of photo theory as it applies to current practice from both the viewpoint of maker and consumer. The course is designed to address philosophical issues for photographers working now and will favor conversation over written work; students are expected to fully participate in critical analysis and discussions. Readings include works by Roland Barthes, Stephen Shore, Susan Sontag, Hollis Frampton, John Szarkowski, Robert Adams, Italo Calvino, Berenice Abbott, John Berger and James Elkins. No pre-requisites.

60-245 Portrait Photography

Intermittent: 10 units

Portraiture maintains a unique standing in photography for its direct and collaborative relationship between an individual and a photographer. This course will examine this relationship and the larger contexts which provide the conceptual framework for deriving meaning and understanding from an image of another person. We will study the theoretical and practical aspects of portrait photography in both studio and environmental settings, providing students with an understanding of the genre by developing both technical and conceptual skill sets. Students will utilize analog and digital equipment, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation. Students will gain knowledge in the development of portraiture through the work of notable figures in the medium's history and contemporary field, including August Sander, Dorothea Lange, Walker Evans, Dawoud Bey, Milton Rogovin, Rineke Dijkstra, Zoe Strauss, Susan Lipper, Justine Kurland, Stefan Ruiz, Larry Sultan, Carrie Mae Weems, Roy DeCarava and Alec Soth. Class discussions, readings and critiques will provide an outline for completing both single and serial image assignments.

60-250 Intermediate Studio: Painting

Fall: 10 units

This course serves as an introduction to technical, conceptual and historical practices of painting. Through a variety of painting experiences and presentations using oil media, students progress from observational exercises and exposure to materials and techniques to developing personal processes, imagery and ideas. Class sessions include technical demonstrations, illustrated lectures, personal and group critiques.

Prerequisites: 60-157 or 60-150

60-251 Intermediate Studio: Print Media

Fall: 10 units

Printmaking is a process based medium that produces multiples of original artworks. Students will create four works on paper using the following printmaking approaches: Relief (carved), Intaglio (engraved), Lithography (planographic), and Screen Printing (stencil). Each technique's unique set of materials, processes and aesthetics will be explored. This course focuses on traditional tools and processes, but will include utilization of digital images and sources through a critical lens. While primarily focused on the learning of fundamental techniques, the class will also expose students to ways that Print Media can be a tool (physically and conceptually) in contemporary practice. Open to sophomores in the School of Art, or by instructor permission.

Prerequisites: 60-150 or 60-157

60-252 Intermediate Studio: Color

Intermittent: 10 units

In this course, students will learn to employ a wide range of color theories and color systems through hands-on exercises and studies. Studies will be done primarily in paint, with some use of collage and digital media. These exercises will be aimed at mastering a variety of color approaches that will be applicable to each student's own artistic practice. Students will develop, based on their own interests, a cohesive body of work in which to practice and expand on the skills learned through the directed exercises. Studio work will be augmented by lectures, demonstrations, critiques, readings and critical discussion of writings about color.

60-254 Intermediate Studio: Photography

Intermittent: 10 units

A photograph captures a moment of time and freezes it in place. In this introductory course, students will reflect on their own lives, capturing people, places and things, through portraiture, interior space, landscape and still lifes. We will consider the formal qualities of light, composition, color, sequencing, editing and print as we take, shape and print our own digital photographs. The course will be framed by field trips, readings, discussions and presentations that look at how artists make photographs.

60-260 Intermediate Studio: Imaging

Fall: 10 units

TBA

60-263 Intermediate Studio: Graphic Novel

Intermittent: 10 units

In this course, students will critically and creatively engage with the medium of comics to learn how to better communicate their ideas in this format as well as challenge its boundaries. A substantial portion of the course will focus on familiarizing students with the basics of storytelling in a sequential narrative format and creating opportunities for students to discover, hone and explore their own voice and style. In addition to creating new work, students will also explore the history of comics and the origins of the "modern" graphic novel. Students will also be exposed to both graphic and non-graphic artists whose works has challenged and redefined the genre. We will explore these artists in order to understand how our own work borrows from and draws upon a rich lineage. Students will also be expected to think beyond the commonly accepted notions of comics and to question the relevancy of their work in this medium. Finally, each student will produce a new body of work that will culminate in the production of a 4-5 "page" "sequential" narrative.

60-276 Photography and the Ephemeral

Intermittent: 10 units

Photography and the Ephemeral is an interdisciplinary photography course designed for students of various disciplines interested in exploring the relationship between images and the ephemeral: things that last only a short moment in time. Throughout the semester students will explore different themes and ways to approach ephemeral imagery such as; still lifes, installations, performances for the camera, and the short-lived nature of images both physical and digital. Participants explore these themes through weekly presentations, discussions, assignments, and critiques.

60-277 Constructing Meaning with Photographs

Intermittent: 5 units

Constructing Meaning with Photographs will discuss ways in which multiple images can be used to expand upon and clarify the intended message of individual photographs and a visual series in whole. Throughout this half-semester studio course, students will work through a variety of approaches to image sequencing and editing. At the start of the course, students are expected to have a significant body of completed work or an easily accessible archive of print resolution images (100+ images) to work with for out of class assignments. Using their archive, they will edit sequences for different presentation methods including gallery exhibitions, books and zines, websites, linear displays, and print portfolios. Weekly in class editing exercises will conceptually correspond with out of class assignments to allow for experimentation and conversation around different approaches to photographic sequencing. Lectures, readings, guests, exhibition visits, and book presentations will provide additional support for understanding how to use photographs in series to build meaning.

60-278 Infinite Rooms: Photography and Installation

Intermittent: 10 units

Infinite Rooms is an interdisciplinary photography course designed for students of various backgrounds interested in exploring the relationships between place, images, and installation. This course will investigate the methodologies of how a place is documented, constructed, and imagined in photographs. This class will introduce a critical survey of images, films, and texts from artists who work at the intersection of installation and images. Throughout the semester various prompts will introduce different frameworks for thinking about photography and installation, such as the dramatic; the psychological; and the personal. Students will utilize digital and analog equipment, learn how to use a large-format view camera, learn studio lighting techniques, develop approaches to working with natural light, and explore methods of printing and presentation.

60-279 Photo and the Ineffable

Intermittent: 10 units

This course explores the relationship between photography and the indescribable, intangible, and hard-to-see. From the spiritual, to the sublime, to the abstract; we will review different frameworks for thinking about the ineffable and how it relates to photographic work. Students will explore these themes through weekly presentations, discussions, assignments, writing workshops, and critiques. We'll look at artists who think critically about photographic representation and investigate a heightened sensorial interpretation of the world. This class will encourage experimental methods and approaches to photography.

60-333 IDEATe: Animation Rigging

Spring: 10 units

Animation Rigging explores processes for building digital skeletons and control systems to drive computer animated forms. This course investigates vital techniques and concepts to create expressive, fully articulated characters for computer animation, film, and game production. Beginning with rigging fundamentals, coursework will advance through various systems and methods that are needed to convey motivated movement and expression in a variety of character forms. Certain key topics include kinematics, joint orientations, driven keys, direct connections, space switching, corrective blend-shapes, custom attributes and graphic user interfaces (GUIs), skinning and deformation. Additionally, coursework provides an introduction to scripting methods for rig creation, including expressions, Python, and MEL. Students will be provided a valuable range of tools that meet production standards for animated film and game creation, as well as a necessary conceptual framework to enable complex problem solving at all levels of rig creation. Anyone interested in the artistic and technical sides of computer animation are encouraged to enroll. Previous experience with Autodesk Maya/3D animation is preferred.

60-335 IDEATe Special Topics in Animation: Story Development

All Semesters: 6 units

IDEATe Special Topics in Animation: Story Development provides insight and strategy for animated storytelling in film and media production. This mini-studio seminar draws upon diverse historical examples to highlight storytelling strategies across cultures and production paradigms. Over this seven-week course, students will develop their own original stories in the forms of scripts and pitch packets, to be later produced as animated content. Discussion and critique will cultivate storytelling skills with greater understanding for audience, form, and cultural context, providing essential tools for communication through animation.

60-337 IDEATe Special Topics in Animation: Storyboarding

All Semesters: 6 units

IDEATe Special Topics in Animation: Storyboarding focuses on the translation of stories and ideas into sequential image boards for animation. This mini-studio seminar exposes the visual grammar of filmic storytelling through analysis and production of storyboards and animatics. Over this seven-week course, students will develop their own original storyboards and animatics to be later produced as animation. Analysis of historical examples will reveal strategies for storytelling through sequential narrative and animation. Discussion and critique will cultivate storytelling skills with greater understanding for audience, form, and cultural context, providing essential tools for communication through animation and design.

60-350 Professional Development for Creative Practices

Fall and Spring: 9 units

This course is intended to expose students studying in creative fields to the basic principles, skills and functions of business used every day in creative practices and industries. Supporting a creative practice - whether an individual studio practice, a temporary collaboration or commission, or an incorporated business or non-profit - all require a foundational knowledge of basic organizational, legal, and financial structures and practices. Throughout this seminar-style course, students can expect to develop a starting knowledge of basic business concepts; learn a foundational understanding of ethics and best practices in business; develop problem-solving skillsets and methodologies for managing creative projects and programs; and practice applying these learnings to their own creative practices. Topics covered will include, but are not limited to: basic business structures; intellectual property; Contracts and employment; methods for generating income and fundraising; financial management and taxes; marketing and communications; negotiation and compromise; and elements of business strategy development. This course assumes no prior background in business education or administration experience.

60-351 Entering the Artworld: Mapping a career path in an uncharted artworld

Intermittent: 9 units

Building a career as an artist is a nuanced endeavor that looks different for each individual. Unlike other fields, where a set professional structure ushers graduating students into a career, the artworld is self-navigated. This course gives artists a foundational understanding of the multifaceted profession they are entering, where they will learn about key support structures like museums, commercial galleries, DIY spaces, residencies, and much more. They will also train in a wide range of concrete skills, including writing artist statements, creating a network, building an online presence, and pricing an artwork. The goal of this class is to give students the awareness, skills, and resourcefulness they need to chart their own course as a studio-based fine artist in an artworld that's ever-changing.

60-352 NOISE: Toward a Critical Theory of Sound and Hearing

Intermittent: 9 units

This seminar will explore audio art in its widest sense: sound sculpture and installations, radio art, the soundtrack, just about anything audible but not conceived as music. Special focus on the production (and reception) of sound by artists, amplifying those creative efforts that, in having explored acoustics, soundscapes, and listening, might also serve to inspire students to incorporate sound in their own work. Contemporary critical theory, by and large, is still glaringly silent on aurality and auditory phenomena; it seriously fails to consider sound as an object of study, instead focusing quite exclusively on visual culture (film, TV, video, computer screens, which are, of course, technologies of vision and sound). This seminar will address this roaring silence by examining some suggestive but disparate theoretical work related to sound and by engaging with a range of artistic practices that explore the production and reception of sound itself.

60-353 Critical Studies: Media Performance - History, Theory, and Contemporary Practice

Intermittent: 9 units

During the last decade of the twentieth century, new technologies have transformed the way we think about live performance. By examining the use of media (analog and digital) across the areas of sound/music, dance, theater, performance art, gaming, and installation, this course will traverse multiple theories and practices of performance history. With an eye to how changing theories of performativity have influenced how artists think about what it means to "perform," this seminar, in a sense, will be engaged in both philosophical and aesthetic research about how technology has changed the conventions of performative artistic practice. What was the role of technology in the dematerialization of the object of art? How have ideas about virtual, parallel worlds changed the way artists think about the "performing body?" If technology once acted as a prosthetic device, increasing an artist's sensual and perceptual world, what happens to the role and impact of an artist's work in the seemingly inert realms of programming or the increasingly autonomous areas of Robotic Intelligence? What does art look like in a post-internet age?

60-356 Critical Studies: Once Upon A Time: A Survey of International Fairy Tale Film

Intermittent: 9 units

Fairy tales have been a part of cinema from the beginning. Since George Melies 1899 Cinderella, filmmakers from across the globe have returned to the genre not only for escape into enchanted worlds, but also for social critique, with stories of injustices avenged, class oppression overthrown and gender roles expanded. In this course we will decenter the narrow conception of the genre fixed by Disney and Hollywood directors to examine fairy tale films from around the world. We will encounter the emergence of a renewed poetics and politics of wonder in international films about transformation, wish-fulfillment and reversals of fortune that deliver a situated counterpoint to the hegemony of a colonizing and commercialized poetics of magic. The transformative power of fairy tales can be approached from a variety of angles. We will analyze how stories themselves function as shape-shifters, morphing into new versions of themselves as they are retold and as they migrate into other media. Beyond looking at the films as texts we will consider the affective qualities of how their formal and aesthetic aspects create wonder, delight, humor, apprehension and terror. What are the stakes of the fairy tales varied transformations today, for whom? Films screened may include: Kwaidan (Japan, 1964), Barbe Bleue (Bluebeard, France, 2009), El Laberinto del Fauno (Pan's Labyrinth, Mexico-Spain, 2006), Xala (Senegal, 1975), The Mermaid (China/Hong Kong, 2016), The Juniper Tree (Iceland, 1990), Peau d'Ane (Donkey Skin, France, 1970), Drei Haselnusse fur Aschenbrodel (Three Wishes for Cinderella, Czechoslovakia-GDR, 1973), In The Company of Wolves (UK, 1984), Hansel and Gretel (South Korea, 2007), November (Estonia, 2017), Tropical Malady (Thailand, 2004) and many more.

60-357 Critical Studies: Nation's Nature - Art, Environment and the American Landscape

Intermittent: 9 units

This course will explore how representations of the American landscape create an ever-shifting national identity. Slogans like "Make America Great Again" trade on nostalgia and a desire for a fixed narrative but ignore the experience of marginalized groups. The actual environment, meanwhile, is being destroyed by the same people who use it as a symbol of power and purity. From painting to photography, print, animation, sculpture and social practice, we will consider how art has fueled or challenged nationalism, patriotism, American exceptionalism. Readings in historical texts, narrative essays and cultural geography, along with discussions and presentations will provide art students a broader context for their own research.

60-359 Critical Studies: Playful theory: critical topics in game culture

Intermittent: 9 units

This hybrid seminar course combines games studies, game criticism, and research-based art to examine the history, contexts, and frontiers of play. Digital and analog games will be approached through a variety of lenses: games as rituals, systems, performances, military technologies, drugs, narrative engines, gendered spaces, commodities. While not geared toward the technical development of videogames, the coursework will include creative projects beyond writing and discussion. The goal is to provide conceptual tools to enrich your design/art practice and tackle a variety of critical topics in a playful but rigorous way.

60-362 Critical Studies: Art Writer: Writing as Object, Criticism, and Experiment

Intermittent: 9 units

ART WRITER will strive to bring together the intersecting discourses of artists use of writing as an object, art criticism, as well as experiments by both artists and critics to use theory as invention. The idea of experiment implied here emphasizes the urgency that art writing move beyond its own history, beyond the received understanding of its proper practices in order to propose new modes of critical reflection. The form and material force of language will be explored through the conceptual and critical work of Dan Graham, Lawrence Wiener, Donald Judd, Lee Lozano, Joseph Kosuth, Vito Acconci, Mel Bochner, Eleanor Antin, the international projects of Art and Language, Fluxus, as well as more recent iterations. This is a writing intensive seminar with experimentation at its core. Members will workshop their writing: revise, rethink, perform, and publish.

60-364 Critical Studies: Decolonize Now!

Intermittent: 9 units

This course explores ways to "delink" artmaking and its history from the "colonial matrix of power." Examining critical discourses surrounding decoloniality, as well as post-coloniality, students will test and complicate foundational concepts such as hybridity, empire, migrant subjectivity, consciousness of the Borderlands, post-occidental reason, pluriversality, and transmodernity. Over the duration of the semester, students will be tasked to form a corroborated viewpoint of their own in relation to theoretical texts by Walter D. Mignolo, Frantz Fanon, Okwui Enwezor, Gloria Anzaldúa, Rey Chow, Hamid Dabashi, Gayatri Chakravorty Spivak, Rob Nixon, Michael Hardt and Antoni Negri, Edward Said, Homi Bhabha, Paul Gilroy, and others. Artists under consideration may include H and #233;lio Oiticica, Walid Raad, Tavares Strachan, MLT Collective, John Akomfrah, Dahn Vo, Trinh T. Minh-ha, Lubaina Himid, Jimmie Durham, Jeannette Ehlers, Martine Gutierrez, Coco Fusco, Lorraine O'Grady, Judy Baca, and ASCO. Exhibitions such as *The Other Story: Afro-Asian Artists in Post-War Britain (1989-90)*, *All the World's Futures, Venice Biennale (2015)*, *Verboam and #233;rica (2017)*, *Decolonizing Appearance (2018)*, *Memories of Underdevelopment: Art and the Decolonial Turn in Latin America, 1960-1985 (2018)*, *May You Live In Interesting Times, Venice Biennale (2019)*, *The Warmth of Other Suns: Stories of Global Displacement (2019)*, and *When Home Won't Let You Stay: Migration through Contemporary Art (2019)* are crucial in understanding the framework of this class. Remember Anzaldúa's words: Because I, a mestiza, continually walk out of one culture and into another, because I am in all cultures at the same time, *alma entre dos mundos, tres, cuatro, me zumba la cabeza con lo contradictorio. estoy norsteada por todas las voces que me hablan simult and #225;neamente.*

60-365 Critical Studies: Queer Power in Art Theory

Intermittent: 9 units

Queer power is a form of (anti-)knowledge that demystifies phallogocentrism and neuters heteronormativity. This class examines how queer theories empower - and can originate in - art making and its history. Over the course of the semester, students discuss recent publications in the field such as Rogers Brubaker's *trans: Gender and Race in an Age of Unsettled Identities (2016)* and Paul B. Preciado's *Testo Junkie: Sex, Drugs, and Biopolitics in the Pharmacopornographic Era (2013)*. Students also investigate recent exhibitions exemplifying oppositional epistemology such as *Trigger: Gender as a Tool and a Weapon (The New Museum, 2017-18)* and *Hide/Seek: Difference and Desire in American Portraiture (National Portrait Gallery, 2011)*. Interweaving the canons of queer thoughts with newer voices such as Lee Edelman, Tim Dean, and Maggie Nelson, this class contextualizes Paul Mpagi Sepuya, Tschabalala Self, Wu Tsang, and other artists who embody queer power today.

60-372 Critical Studies: The Precarious Body in Contemporary Art

All Semesters: 9 units

This seminar will examine images and projects in contemporary art that deal with debates concerning ideas that had already begun brewing in the 1980s and early 90s. Artists and theorists tended to address issues of institutional violence as "discourse," or to explore ideas of difference and alterity as "abjection." More recently, the idea of precarity has taken central stage as a way of thinking through, and taking action against, the kinds of structural oppression that deem certain groups of people vulnerable to repeated forms of aggression, poverty, and displacement without protection. A major part of the course will examine how contemporary artists address the precarious body as an important site for political and aesthetic resistance.

60-374 Critical Studies: Picturing Asian America

Intermittent: 9 units

Asian American art is not Asian art. Asian art is not Asian American art. The conditions in which we make art in the United States have always been unique: our art has evolved to be antiracist, anti-patriarchal, and for the sake of the undercommons. Expanding oppositional consciousness, the historical context for our exploration and inquiry is enriched by Asian American literature and film; we welcome and renew the lessons of our shared minor feelings. This class also celebrates the Asian American history of collaboration with other BIPOC (Black, Indigenous, and People of Color) communities and the tradition of intersectional artmaking against the hegemonic canon.

60-378 Critical Studies: Science Fiction Film

Intermittent: 9 units

Science Fiction Cinema offers an idiosyncratic survey of the science fiction film genre. More than just a form of entertainment, science fiction is a powerful tool for exploring our hopes, fears, and dreams about the future. This class reveals how science fiction films often grapple with philosophical and ethical questions about the nature of humanity and our place in the universe. Together we will explore how filmmakers have used the science fiction film genre to explore both the timeless human condition and the complex issues of their time. In addition to studying the films themselves, we will consider the various cultural, social, political, and technological contexts in which they were created as well as how the films have themselves influenced society and culture. Additionally, we will examine the creative and technical innovations that filmmakers use to create stunning and thought-provoking works of art. Throughout the course, we will watch and analyze a variety of science fiction films, from international and independent productions like *"World on a Wire"*, *"Stalker"* and *"Advantageous"* to blockbuster and studio productions like *"Nope"*, *"The Wandering Earth"* and *"The Matrix"*. Through weekly readings, film screenings, and class discussions, students will learn to analyze film as a creative medium of social commentary and critique. Assignments will include personal written responses to the films and readings, visual essays, and creative projects.

60-398 Critical Studies: Social History of Animation

Intermittent: 9 units

Social History of Animation will investigate the history of animation from early experiments with trick film through the development of major studios, to independent animation, web based work and emerging forms. Animation will be analyzed and discussed in relation to the social movements and technological innovations that effected animators and their work. This class will read related texts and view examples from around the world to explore animation as a means for personal expression and as a reflection of the context in which they were made.

60-399 Art History/Theory Independent Study

Fall and Spring: 9 units

A tutorial course in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of the School of Art. Prerequisite: Art junior or senior status, or by instructor permission.

60-400 Senior Review

Spring

Students present their work and their ideas about their work to a faculty committee. This review affords graduating students the opportunity to analyze and summarize their work, and to engage a faculty committee in discussion about issues that face an artist preparing to enter a career in art. Although this is a non-credit course, it is required of all Art (BFA, BHA, BSA and BCSA) seniors.

60-401 Senior Studio

Fall: 10 units

The primary goal of Senior Studio is to create a context for students to develop and realize an ambitious and self-defined creative project. With the guidance of faculty, each student will pursue their own artistic goals and develop their ability to sustain focused artistic activity while developing their own voice. Additionally, Senior Studio will help students to: Foster a community and shared sense of purpose in an atmosphere of mutual support, critical dialog, knowledge exchange and camaraderie; Cultivate and apply professional practice skills by preparing for life after graduation; Participate in studio visits with a multidisciplinary team of faculty, visiting artists and critics; Collaboratively produce a successful Open Studio event on the last day of the semester.

60-402 Senior Studio

Spring: 10 units

Students continue a comprehensive two-semester capstone project. Each student pursues an ambitious and cohesive body of work with guidance by a team of School of Art faculty. Multimedia, multidisciplinary, and collaborative work is encouraged. Studio work is supplemented by group critiques, workshops on writing, professional presentation skills, career preparation, and technical instruction as needed.

60-403 Senior Critique Seminar

Fall and Spring: 10 units

Senior Critique Seminar comprised of group discussions that analyze the conceptual and aesthetic frameworks that surround each student's individual studio practice. The course supports independent inquiry, mature studio practice and both an in-depth critical reading of visual art and an increased comfort in the articulation of ideas and processes. Each student can expect two or more hour-long critiques throughout the semester, paired with ample time for individual studio work. These course discussions will also be informed by the Visiting Artist Lecture series and concepts and concerns carried from studio and academic seminar classes.

60-406 Advanced ETB: Internet Resistance

Intermittent: 10 units

Through booms and crashes, colonizations and disruptions, IPOs and LOLZ, Internet has been a spectacular laboratory of social conflict. But what can artists do on the net beside tweaking their pitiful portfolios and sinking into social media malaise? What is the function of the network in the age of pervasive surveillance, fake news, and filter bubbles? How to Internet under the First Troll President of the United States? Internet Resistance is both a schizo-seminar about critical issues in cyberculture and a trans-media studio to develop terrible ideas for the networked society. <http://internetresistance.molleindustria.org/>
Prerequisites: 60-210 or 60-110

60-407 IDEATe: Experimental Sound Synthesis

Spring: 9 units

This is a course that will guide students into the world of experimental approaches to music and sound production, with particular emphasis in some of the key practices and concepts developed in the 20th and 21st centuries. We will examine a variety of ways in which sound works are made and perceived; understanding the historical perspectives and critical viewpoints of each approach through the application of hands-on practicum. The topics covered in the course are divided into three large areas: the art of sound, the use of technology in the production of sound works, and the creation of interdisciplinary sound installation. Students from different disciplines will work together to collaborate on the designing, prototyping and execution of a series of ambitious projects in response to the topics covered in class.

Course Website: <https://courses.ideate.cmu.edu/57-344> (<https://courses.ideate.cmu.edu/57-344/>)

60-408 Advanced ETB: Digital Storytelling and Resistance

Intermittent: 10 units

Digital Storytelling and Resistance is a class through which students will explore the varied ways artists use contemporary technology to create complex alternative stories to dominant media narratives as well as the ways in which video, film, performance and media artists have historically used hybrid documentary storytelling practices and appropriation as a way to resist, respond to, and deconstruct one-dimensional news media and pop cultural stories. In this course students will create video essays, remix and appropriation-based works, hyperlinked interactive stories, modded games, written pieces and interactive moving-image based narrative works through new multimedia publishing platforms.
Prerequisite: 60-110

60-409 Advanced ETB: Video & Performance

Intermittent: 10 units

This studio course will concentrate primarily on the historical and ongoing relationship between video and performance. That said, this course will be flexible enough to allow students to create video, performance and video/performance projects. For structured projects, all students will be expected to participate in performance. Class time will be spent considering the history of performance and video/performance, viewings of primarily video/performance works to provide background and inspiration, presenting and critiquing student projects and studio time to work on projects. Technical instruction in video editing, compositing and effects, audio recording/editing and midi applications will be offered on an as needed basis.
Prerequisite: 60-110

60-410 Advanced ETB: Moving Image Magic: Visual Effects and Motion Graphics

Intermittent: 10 units

Fly like Harry Potter, fall into Alice's looking glass, create new worlds, or take a head-trip into the inner reaches of your subconscious. It's all possible in Moving Image Magic! This course serves as an introduction to the creation of extraordinary cinematic visions using a variety of analog and digital tools and techniques. These include: digital compositing, miniatures, motion tracking, rotoscoping, matte painting, puppets and motion graphics. Primary software tools are After Effects and Photoshop with forays into, Motion, Resolve, Logic and Smoke. Prerequisites: Electronic Media Studio: Introduction to the Moving Image or instructor permission.
Prerequisite: 60-110

60-412 Interactive Art and Computational Design

Intermittent: 12 units

This is an advanced studio course in arts-engineering and new media practice, with a special emphasis for Spring 2016 on mapping and information visualization using geographic data. Topics surveyed in the course will be tailored to student interests, and may include: experimental interface design, locative and mobile media, data-driven activism, image processing and computer vision-based interactions, and other topics. Through a small number of exploratory assignments and a public capstone project, students will bolster interdisciplinary problem-solving abilities and explore computation as a medium for curiosity-driven experimentation. Enrolling students are expected to have demonstrable programming skills, without exception, beyond the level of an introductory class such as 15-112. Although the course will provide technical overviews of major visualization toolkits (including D3, Processing, and openFrameworks), assignments may be executed in the student's preferred programming environment. Graduate students should register for section 51-882, 60-712, or 62-726, which meets with the undergraduate sections 60-412 and 51-482.
Prerequisites: 15-110 or 60-112 or 15-112

60-413 Advanced ETB: Real-Time Animation

Intermittent: 10 units

An exploratory studio that considers improvisational strategies for making animation within real-time computer graphics frameworks. Advancements in virtual production, real-time computer graphics engines, and visual programming tools for AV synthesis provide open frameworks for the exploration of animation in spatial and interactive contexts. Studio work will explore real-time animation in a variety of contexts, including screen-based interaction, site-specific installation, and spatial immersion. Conceptual frameworks drawn from the histories of animation, video art and Expanded Cinema, and immersive media design will inform collaborative group work and class discussion. Students without the prerequisite may register by instructor permission.
Prerequisites: 60-210 or 60-110

60-414 Advanced ETB: Animation Art and Technology

Spring: 12 units

Animation, Art, and Technology is an interdisciplinary, Art and Computer Science, cross-listed course. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which interdisciplinary teams of students can produce animations across platforms from single channel to augmented reality. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya and Unity leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and immersive technologies.
Prerequisites: 60-125 Min. grade C or 60-110 Min. grade C or 60-220 Min. grade C or 60-333 Min. grade C

60-415 Advanced ETB: Animation Studio

Fall: 10 units

This is an open animation studio for students who want to improve existing animation skills and develop a personal animated short. The class will introduce a variety of techniques and concepts for animation production. Using both 2D and 3D tools, animation will be explored through short assignments designed to develop diverse skills and ideas. Each student will develop and produce a short animation. The class will engage in discussion and critique of each other's work along with examples of historic and contemporary animation.

Prerequisites: 60-220 Min. grade C or 60-110 Min. grade C or 60-333 Min. grade C or 60-218 Min. grade C or 60-125 Min. grade C

60-416 Advanced ETB: Documentary Storytelling

Intermittent: 10 units

In this class students will develop projects which use a variety of narrative concepts to convey stories in new ways. We will begin with a core practice around video, audio, and expand into internet media, performance, physical media and installation. Emphasis will be placed on story structure and strategies for choosing a media most appropriate to the narrative as well as the desired audience. Works by Janet Cardiff, Errol Morris, Spalding Gray, Werner Herzog, Laurie Anderson, This American Life and others will be mined for inspiration. With permission of instructor. We will also examine and discuss a range of historical and contemporary strategies employed by art makers who have used forums from on-line and virtual spaces to physical and site specific venues to expand and explore the relationship between the art object and the audience.

Prerequisite: 60-110

60-417 Advanced ETB: Video Art

Intermittent: 10 units

In this advanced studio course, students will focus on creating experimental works of video art exploring a variety of both historical and contemporary approaches to the field. Building from their prior foundational moving image courses, students will have the opportunity to dive deeply into an array of formal and conceptual approaches to the medium. Throughout the semester, students will produce several major assignments focused on the production of video artworks exploring visual effects and abstraction, documentary forms and video essays, performance-for-video, generative video, and multichannel media installation. Each assignment will be supported through relevant video and audio technical demonstrations. Additionally, all the major assignments will be supported by reading and screening homework, benchmark check-in assignments, workshops, visiting artist lectures, and in-progress meetings and amp; critiques. This class will give students the opportunity to independently explore their evolving material and conceptual interests within the language of video and allow students to develop their own research and fabrication strategies unique to their ideas with a supportive community operating in dialogue throughout the planning, making, and exhibiting process. The class will culminate in a public screening event at the end of the semester.

Prerequisite: 60-110

60-419 Advanced ETB: Experimental Game Studio: Digital Playgrounds

Intermittent: 10 units

A hands-on intermediate course focused on immersive environments, world building, and real time experiences pushing the boundaries of gaming. On a conceptual level we'll look at practices within digital art and independent game development: virtual architecture and sculpture, walking simulators, avatar-based performances, interactive art, procedural animation, environmental storytelling. On a technical level the course will introduce you to 3D modeling (Blender), game engine workflows and scripting (Unity) forming a scaffolding for advanced Electronic and Time-based courses.

Course Website: <http://mycours.es/>

60-422 Advanced ETB: Experimental Animation

Spring: 12 units

[IDeATe course] This class will examine animation production from the student's perspective. Animations that explore both form and content will be developed and discussed. Topics will include; non-linear narrative, visual music, puppeting, non-traditional materials, manipulation of motion and performance capture data and immersive environments.

Prerequisites: 60-220 or 60-333 or 60-110

60-425 Adv. ETB: (Im)Possible Worlds: 2D Animation, Motion Graphics and Visual Effects

Intermittent: 10 units

While developing proficiency in Adobe After Effects (and other tools) students will explore the experimental worldbuilding and storytelling possibilities of hybrid moving image media. This course is structured around technical tutorials and workshops, readings and screenings, the creation of collaborative and individual moving image projects, discussion and critique. Some of the themes we will explore include "The Fantastic" as expressed in the genres of horror, science fiction and fantasy. Artists whose work we will look to for inspiration include Jacolby Satterwhite, Shana Moulton, Rachel MacLean, Rachel Rose, Charles Atlas, Sondra Perry, Max Almy, Nam June Paik, Stan Van Der Beek, Zach Blas, Laurie Anderson, Cecile B. Evans, Ryan Trecartin, and many others.

60-428 Advanced ETB: Drawing with Machines

Intermittent: 12 units

This is an advanced studio course in experimental drawing, generative art, computational design, and mechatronic mishegas. Working at the boundaries of code, automation, physical materials, and gestural mark-making, we will explore personal and peculiar new approaches to digital fabrication; the development of ultra-niche workflows as a mode of creative practice; and the use of algorithms and machine collaborators as nontraditional intermediaries between mind, hand, and paper. Units in this course include: rule-based art and conditional design; chance and stochastic composition; real-time interaction and contingency; asemic cartography; synthetic automatism and ersatz perception; and more. Through rigorous exercises in freestyle computing, participants will develop skills in the control of machines by (e.g.) AxiDraw, Line-Us, Scribit, Rotrics, and Universal Robots to govern line, texture, tone, shape and mass in a variety of wet and dry drawing media. Interested students should have a portfolio of creative visual work, and programming experience equivalent to an introductory course such as 15-104, '110 or '112. Enrollment by permission of instructor.

60-429 Advanced CP/ETB: Digital Worlds: Making and Performing in Digital Contexts

Intermittent: 10 units

In this class students will look at digital spaces including social media, chatrooms, online galleries, phone applications, YouTube, 3D renderings, massively multi player online games, and more to produce works that respond to the specificity of these terrains. There is a rich history of site specificity and contextual practice in the physical world; this class will consider parallels in computer-based environments. In addition to theory and research components, students will develop a variety of technological skills in video production, webcasting, audio editing, gif animation, 3D modeling, and more in this course.

Prerequisite: 60-110

60-430 Advanced SIS: Open Sculpture

Intermittent: 10 units

Sculpture is perhaps the broadest field among the contemporary visual arts. Through its privileged relationship to the physical world and the viewer's body, sculpture is the glue that connects the intermedia practices of object, installation, interactive art and performance. In this class we build on skills and concepts learned in 3D media 1 and 2 to develop students' individual approach. Students define independent responses to topics proposed through discussion of contemporary sculptors. Emphasis is placed on individual development. Students are encouraged to explore interdisciplinary approaches.

60-431 Advanced SIS: Installation

Intermittent: 10 units

This course explores a broad range of sculptural issues concerning the practice of Installation Art. This Studio course will primarily emphasize immersive environments (but not necessarily), given the circumstances of remote learning and one's bedroom as studio, or a similar venue, small and intimate may be more appropriate. Students expected to involve an ensemble of elements: objects, (found, purchased, reused, appropriated), made from an array of any kind of materials including natural materials; combined with time-based media; video, audio, performance, light etc. to create relationships within a particular space possibly as a 'site specific' venue in order to immerse the viewer within. Consider the notion of an immersive stage set, and the importance of documentation, 'Fabricated To Be Photographed, Video graphed, Digitally Imaged and/or Performed In.' Emphasis is on research about "place" and the proposal process for a specific context. Various artists, strategies, methods and materials will be investigated through projects, readings, lectures, visiting artists and discussions. Exercises and gestures are assigned initially, then students are expected to propose and establish their own projects/practice later in the semester.

60-433 Advanced SIS: Ceramics

Intermittent: 10 units

Clay is a primary building block of sculpture. This supple, responsive and versatile material is being incorporated into the work of many contemporary artists today. This class will ask students to create projects that explore the use of clay as a medium in the context of their own work. It is intended for students who would like to specialize in clay sculpture, as well as students who work primarily in other mediums. Projects will originate from self-generated ideas. Class critiques will stress group participation to broaden viewpoints and sharpen critical abilities. The majority of class time will be for studio projects. The use of mixed media is allowed. A materials fee is required.

60-435 SIS: Metals

Intermittent: 10 units

Studio focus on fabrication using light metalworking techniques including forming, joining, and finishing. Metalsmithing and jewelry techniques will be explored in the context of sculptural issues. Metal stretching, forging, brazing, texturing, small scale casting and coloring are also presented. Slides looking at small scale metalwork, as well as contemporary sculpture using metal techniques will be presented periodically. Metals provided include copper, brass, and bronze sheet and wire. Materials fee will also cover silver solder and other expendables. This is a repeatable class that will add to the tools and techniques acquired in earlier metals classes while expanding individual growth within the concept and context of sculpture.

60-437 Advanced CP/SIS: Environmental Sculpture

Intermittent: 10 units

Studio focus on sculpting with the environment. Includes object making, installations and site work with an emphasis on ecological themes: eco-material use and reuse, growing systems, environmental impact and a variety of other related issues. The semester is structured with initial exercises and a series of small gestures that lead to a major project. Students are required to explore and to develop proposal making skills in order to implement a site-specific project; either real or virtual. Students to produce a project complete with a well-documented outcome to include: visual representation, research and written descriptions.

60-440 Advanced SIS: Sculpture After the Internet

Intermittent: 10 units

Hito Steyerl asked, "Is the internet dead? ...[it is] completely surveilled, monopolized, and sanitized by common sense, copyright, control, and conformism... what happened to the internet after it stopped being a possibility?" This course assumes it is the artist's role to find and create possibilities in all contexts, and investigates what it means to create new possibilities by making physical objects, experiences, sculptures, installations, and systems in an era post-internet. As a project-based experimental lab, this class asks students to navigate back and forth between digital and physical creative tool sets to create new works. We will take inspiration from the history, theory, ideologies and technologies surrounding the internet, as well as from artists, animators, and engineers working on and around the internet today. We will explore issues surrounding automation, digital fabrication, and online maker / fabricator culture as tools to be used, but also as socio-political forces. Other concepts we will explore as a group include the relationship between body and technology; cybernetics, robotics, AI, and the uncanny valley; the relevancy of hand-making and physical construction post-automation; "image-objects;" scripted spaces; the producer-consumer continuum; the divisiveness and productiveness of online subcultures; anonymity; accessibility of information and production tools; and the spatial and temporal effects of inhabiting both digital and physical worlds. If we understand our current epoch as an era dominated by onscreen and networked experiences, this course investigates what it means to embrace, explore, explode, celebrate, negate, critique, reverse, or oppose that through the making of sculpture, broadly defined. This course assumes knowledge of at least very basic 3d modeling, and/or physical computing, and/or coding, and/or 3d media fabrication/construction techniques.

Prerequisites: 60-130 or 60-131 or 60-210 or 60-134 or 60-212 or 60-133 or 60-132

60-446 Advanced SIS: Expanded Theater Fusion Studio

Intermittent: 10 units

[IDeATe collaborative course] As the boundaries between theater, art, entertainment and everyday life continue to expand through engagement with new technologies, it is critical that emerging artists and technologists be provided with the tools, language, and vision to thrive in the new millennium. Expanded Theater will reanimate classical modes of performance with media, networks, robotics, locative applications, and mobile systems. Considering theater as an ancient technology of mass participation and social cohesion, this fusion studio explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media and storytelling is critical to this approach. Experimentation with new forms can reanimate the basic values of theater; the essential nature of a live event, the possibility of visionary spectacle, and the creation of meaning in dialogue with an audience. Expanded Theater is an opportunity to explore avenues outside of traditional theatrical production modes and beyond each student's individual discipline. The curriculum combines resources from Carnegie Mellon's Schools of Art and Drama, Integrative Design, Arts, and Technology (IDeATe), the Emerging Media Masters (EM2), Computer Science, the Robotics Institute, and their collaborators across the university in a new configuration. Expanded Theater will explore domains ranging from site specific and networked-based performance and interventionist practices, to pervasive social media technologies and their influence on interpersonal communication. The goal is to investigate contemporary languages that allow authors, actors and technologists to collaborate in ways that push beyond our present understanding of theatrical production and reception. This course alternates between two modes of research and design.

60-447 Advanced CP: Art at the End of the World

Intermittent: 10 units

The world is awash today in stories that anticipate an end to the world as we know it. These daunting narratives often anticipate techno-apocalypse, global pandemics, runaway climate change and mass extinctions. Their scale can appear to dwarf the actions of individual humans, and yet this is exactly where the work of the artist is proportionally most significant. Artists write the myths that help us understand the present, and create the monuments that explain the present to the future. They sound the alarm anew when sympathetic ears have grown deaf, and most importantly, they invent hopeful futures that were previously beyond imagination. Students in this course will learn significant historical and contemporary "end times" narratives, both utopian and dystopian, as well as the cultural responses to them. We will be using these as launching points for creatively engaging with our present apocalyptic predicaments. Students will visit regional locations that provide real-world grounding for these stories. They will use joy, introspection, humor, and courage, to create works using the full range of artistic expression from the highly ephemeral to the timeless. This course may never be offered again.

60-450 Advanced DP3: Drawing

Intermittent: 10 units

Figurative art retains aspects of the 'real' world as its subject matter. It has recognizable forms; it shapes, makes likenesses, and represents. Typically, 2D figurative work creates illusionistic depth to create spaces in which narratives occur and are portrayed. Within this realm, our course is unrestrained. All of our observations are valid, stories equal, feelings freed, fears unleashed and proclamations promoted. Projects across painting and drawing are drawn from both perception and invention and include working from the live model. The class will consist of studio time, critique, readings, discussion and museum/gallery visits.

Prerequisites: 60-160 or 60-150 or 60-157

60-451 Advanced DP3: Concepts of Figuration

Intermittent: 10 units

This course encourages creative exploration of the human image beyond observational figure drawing. We will be thinking of the figure as a symbol to explore narrative, anthropological, cultural, sociopolitical, gender, and dream-life imaging. Through these lenses the figure becomes primary to the understanding of personal or group identity, place, sexuality and gender identification. Figure drawing is open to the use of traditional and extreme image making methods including observational and fictional representations or other conceptual premises relevant to the successful presentation of privately held concerns. Emphasis will be on experimentation with both material and image. The class will consist of studio time, critique, readings, and discussion.

60-452 Advanced DP3: Color

Intermittent: 10 units

In this advanced course, students will learn to employ a wide range of color theories and color systems through hands-on exercises and studies. Studies will be done primarily in paint, with some use of collage and digital media. These exercises will be aimed at mastering a variety of color approaches that will be applicable to each student's own artistic practice. Students will develop, based on their own interests, a cohesive body of work in which to practice and expand on the skills learned through the directed exercises. Studio work will be augmented by lectures, demonstrations, critiques, readings and critical discussion of writings about color.

Prerequisites: 60-157 or 60-150 or 60-160

Course Website: <https://sites.google.com/andrew.cmu.edu/colorcourseclaytonmerrell/home> (<https://sites.google.com/andrew.cmu.edu/colorcourseclaytonmerrell/home/>)

60-453 Advanced DP3: Painting

Fall and Spring: 10 units

This course is designed to help promote a painter's development, both conceptually and technically. It encourages students to expand their ideas through a diverse set of projects. Through research and studio experimentation, students will explore issues of scale, surface, materiality, process and performativity in painting. They will also consider notions of the "picturesque" and how non-artistic disciplines can inform painting. Lectures and assignments are designed to enrich the painter's conceptual and technical base and to promote creative growth.

Prerequisite: 60-250

60-454 Adv Studio: Small Things: Quiet interventions, Miniatures & the Power of Everyday

All Semesters: 10 units

This advanced studio class allows for the interdisciplinary exploration of historical, critical, craft-based, and conceptual issues surrounding the Small. The course will look at global and historical examples of small objects and the impulse for humans to make miniatures. It will consider site specific installations and interventions that are often not easily viewable. It is very easy for a large object, an expensive object, to make a big visual and/or social impact. What does it mean to work on a humble scale and with ephemeral and/or accessible materials? How does working small allow for generosity, play and adaptability? This is an interdisciplinary advanced studio course. Students will predominantly work in their own studios and bring their own practice/techniques and research to our conversation.

60-460 Advanced DP3: Paint/Print

Intermittent: 10 units

Paint/Print encourages creative exploration of the boundaries between print media and painting through material investigation, thereby eliminating any assumed hierarchy between the two modes of working. Painting and printmaking are open to the use of traditional and extreme image making methods including observational and fictional representations, abstraction, collage, installation, digital drawing/painting or other conceptual premises relevant to the successful presentation of privately held concerns in image-making. Emphasis will be on experimentation with both material and image. The class will consist of studio time, critique, readings, and discussion.

Prerequisites: 60-250 and 60-251

60-461 Advanced ETB: Experimental Capture

Intermittent: 12 units

This is an interdisciplinary studio course in expanded media practices that arise from using devices and algorithms to "capture" the world. We will explore experimental workflows, ranging from no-tech and low-tech to emerging and state-of-the-art techniques, in order to capture, model, and share new representations of people, objects, places and events. Through self-directed research projects, students will develop systems to capture a wide variety of phenomena, and creatively share the media they collect. We will cover a wide range of techniques and artistic practices that incorporate immersive, panoramic, high-speed, multispectral, and multispectral imaging; depth sensors and 3D scanners; motion capture systems for gestures of the face, body, hand, and eye; computer vision and machine learning techniques for detection, tracking, recognition and classification; and other unusual, forgotten, and nascent technologies for transducing the unseen, ephemeral, and otherwise undetectable.

60-462 Advanced DP3: Painting Matter & Substance

Intermittent: 10 units

This course will be a hands-on investigation of the material, tangible, and physical aspects of painting. Students will learn how to make and use various paints, supports and grounds including oil paint, egg tempera, encaustic, watercolor/gouache, distemper, casein and fresco (in addition to other materials based on student interest). The working properties of various additives to and combinations of these media will be examined and experimented with. Technical issues affecting longevity will be addressed and experimentation will be encouraged. Students will investigate the work of other artists with a forensic "How did they do that?" approach. The second half of the semester will be devoted to studio work focusing on the ways in which each student's personal vision can be embodied and expanded in one or more of the above media.

Prerequisites: 60-150 and 60-250

60-464 Advanced DP3: Expanding the Graphic Novel

Intermittent: 10 units

In this course, students will critically and creatively engage with the medium of comics to learn how to better communicate their ideas in this format as well as challenge its boundaries. A substantial portion of the course will focus on familiarizing students with the basics of storytelling in a sequential narrative format and creating opportunities for students to discover, hone and explore their own voice and style. In addition to creating new work, students will also explore the history of comics and the origins of the "modern" graphic novel. Students will also be exposed to both graphic and non-graphic artists whose works has challenged and redefined the genre. We will explore these artists in order to understand how our own work borrows from and draws upon a rich lineage. Students will also be expected to think beyond the commonly accepted notions of comics and to question the relevancy of their work in this medium. Finally, each student will produce a new body of work that will culminate in the production of a 4-5 "page" "sequential" narrative.

60-466 Advanced DP3: Publishing as Artistic Practice

Intermittent: 10 units

This course will look at the history of artist multiples from artist books and zines, mail and subscription based practices, and editioned objects. Students will be introduced to techniques in traditional bookbinding, zine making as well as design and layout an artist book for mass publication. Studio work will focus on materials and processes that can be found and done at home as well as designing projects that utilize print-on-demand product services. We will be looking at contemporary artist's multiples that exist over a wide range of media, from fine art prints, sculptural and digital editions, and even performance and participatory work conceptualized as a multiple. We will discuss the economy and business structure behind independent publishing, looking into contemporary artists who are running their own presses, an emergence of art book and zine fairs, and envisioning alternative distribution opportunities for our artworks.

60-468 Advanced DP3: Print Media - Sculpture, Installation Screen Intensive

Intermittent: 10 units

This advanced print media course is a screen-printing intensive that moves print out of editioned works on paper. Students will utilize the multiple to create immersive wall installations, participatory social sculpture, objects that act as interventions, and hand-printed yardage that can be used in soft sculpture and/or wearable forms. Students will challenge their screen-printing techniques and the scale and reach of their printed matter. Projects will concern the role of ornamental design within socio-political-cultural frameworks and the role of "hand-made" within exchange and gift economies. Projects will problematize artworks in relationship to the human body: as wearer, as laborer, and as consumer.

60-471 Advanced DP3: Photography/Print Workshop

Intermittent: 10 units

In this course in Photography and Print, students will develop semester-long individual projects in contemporary photography, printmaking, artists' books and/or multiples. Students will work in photography and amp;/ or print media, with an invitation to use either studio-based processes (intaglio, lithography, screenprint, photography lab) or work with hand-printing, digital or nontraditional approaches (monotype, stamps, stencils, rubbings, relief, digital photography). This will culminate in a capstone book, supported by the School of Art. Readings, discussion, critique, and visiting artists will enhance our conversation and research. As a workshop, this course is for students who are ready to explore their work more deeply and create ambitious self-driven projects.

60-472 Advanced DP3: Mutable Landscape

Intermittent: 10 units

With camera in hand, students will explore, document and invent a sense of place in Pittsburgh. Informed by photographic history and landscape studies, students will develop their own portfolios of digital prints. As a CFA Interdisciplinary photography course, students will be encouraged to consider their photographs in the medium of their home department, and in some cases as a starting point for projects in other materials. No prerequisites.

60-474 Advanced DP3: Imaging Liveness: photography and performance

Intermittent: 10 units

Performance art, or the live event, has been a continuous element of art practice throughout most of the 20th century but our evolving technologies of digital recording devices have radically impacted our understanding of performance as a medium of disappearance. With the increased expectation to engage remotely the role of documentation in relationship to the live event has become an inevitability rather than a conscious construction. We are expected to be both a warm flesh body and simultaneously our own image. Considering the proliferation of cameras, the value of photographic representation, it's meaning and potential are critical from within the glut of image culture it becomes crucial to re-examine our corporeal existence and the repercussions of both having a body and being represented as a body. We will discuss the writing of Andre Lepecki, Hito Steyerl, Philip Auslander, Catherine Wood and Rebecca Solnit to deepen our understanding of various historical genres of image construction as they relate to performance and notions of liveness. In this course you will have the opportunity to develop live performances and consider how its documentation can be a transformation of the live event into a work unto itself. We will work collaboratively during in-class workshops; exploring the physical and social aspects of photographic processes in the development of unique event-based photographic methods. Participation in this course will grant you access to a professional digital SLR camera; lens kit, and tripod for the duration of the semester. This course will offer you the time and space to produce new work, take part in advanced critique and research current issues surrounding contemporary photography and performance as they pertain to your individual work.

60-475 Advanced DP3: Open Print

Intermittent: 10 units

This advanced Print Media course focuses on student-driven development of a studio practice focused on contemporary print, multiples and distributed art. In this class, individuals will continue to build on technical skills and concepts, and the interdisciplinary applications of both, through self-directed, individual approaches. This course is for advanced students of art, ready to focus on larger-scaled, conceptually and formally ambitious projects that are formed from long-term investigations.

Prerequisites: 60-475 or 60-476 or 60-474 or 60-468 or 60-473

60-476 Advanced DP3: Serigraphy (Screenprinting)

Intermittent: 10 units

This course is a comprehensive and intensive study of Serigraphy (screenprinting), one of the most versatile and contemporary of printmaking techniques. The course is focused upon the mastery of this process. Students will explore multiple methods of image making (from hand-drawn to digital imaging) and will be introduced to CMYK printing. The emphasis of this course is on artistic work on paper, but will also be exposed to the ways that screenprint can work across a wide range of different media: from 2D (paper, canvas, cloth) to 3D (book forms, sculpture, installations) and utilizing printed multiples in participatory and exchange based artworks.

60-478 Advanced DP3: Photography Stands Up

Intermittent: 10 units

The value of a photograph is most often centered on the work it takes to construct an image but the work of photography does not stop there - printing out an image may also be the first step in building something else entirely. Photography Stands Up will treat the photographic print as a necessity, explore the photographic print as an object and most importantly consider the photographic print as a starting point for creating a significant work. After the past year of remote learning this course has a clear goal of getting students out of their seats, off the computer and away from the screen. This course will demand that we be active with our bodies and driven both conceptually and materially with an emphasis on experimentation as we vacillate between both digital and analog methodologies. We will explore printed photographs as objects that we may bend, fold, scratch, weave, dye, reconfigure and incorporate into future photographs. This course will introduce students to non-traditional methods of working in the Black and White Darkroom and will require students to print their images out on a regular basis using both the darkroom and digital print facilities. We will also explore the vast resource of the shooting studio, which we will use collectively during in class workshops - focused on putting our theories into practice. Participation in this course will grant students access to a digital camera and tripod to use for the duration of the semester and this tool will be a key component to in class workshops.

60-487 Advanced CP: The Amateur

Intermittent: 10 units

If a contemporary artist can truly do and be anything, how come so much art looks the same? More and more contemporary artists are pushing beyond the conventional media and methods of the art world by strategically operating as "professional" amateurs. The term amateur reflects a voluntary motivation to create as a result of personal passion for a particular activity, regardless of expertise or authority. For the artist, embracing the role of the amateur allows for the use of any profession, institution, or social activity as a possible material within their creative practice. This includes artists who "perform" as amateur preachers, psychologists, geneticists, politicians, and exotic dancers; artists who create amateur institutions like sanitariums, circuses, hair salons, talk shows, and planetariums; and artists who collaborate with professional hypnotists, ornithologists, stunt coordinators, ventriloquists, and diplomats in order to manifest their work. Students in this class will work on self-defined projects that utilize the role of the amateur as a critical method for expanding the breath and reach of their art practice into new forms and venues. With faculty mentorship, each student will be responsible for developing their projects through independent research, apprenticeships, and collaborations with experts in fields relevant to their work. Workshops, lectures, and in class critique of ongoing work will look at contemporary trends related to amateurism in art practice, theory, and the world at large. This class is not about being an amateur artist, but about being a serious artist who uses amateurism as a tool. Thus the class is only open to students with ???

60-491 Advanced CP/ETB: Art AFTER The End Of The World

All Semesters: 10 units

Taught by Prof. Rich Pell (School of Art BSA Faculty Advisor and founder of the Center for PostNatural History). This course will take students on a deep dive into our mythological, scientific and artistic understanding of world-changing catastrophic events, from the earliest human stories up to the present moment. Film and writings, fiction and non-fiction will inform a critical conversation about the important role of artists in these times. Contemporary research in science and critical theory will inform the development of unique self-defined creative practices that embrace our most durable human qualities of joy, empathy, humor, and courage. Field-trips (virtual and/or RL) will fuel group discussion and the development of new artistic works open to any media.

60-493 Advanced CP: Out There - Post-Studio Practice

Intermittent: 10 units

Since the Dada movement began to erode the importance of institutional validation, artists have consciously chosen to operate outside of a studio context in a variety of ways. The eighties saw the emergence of movements and artist-run organizations intent on removing institutional barriers for art practice, enabling performance, civic engagement, social and political intervention, and myriad other approaches to feed the dialogues surrounding art and culture. This class will consider the philosophical, ideological, aesthetic, and political motivations, which influence such artists and organizations and will look at writers who have provided a corresponding critical framework. Students will engage in research and reading to develop their own project(s), using the class as a space for dialog and development, and the time outside of the class as the space for execution and manifestation.

60-497 Advanced Studio: Science Fiction

Intermittent: 10 units

"There is nothing new under the sun, but there are new suns." - Octavia E. Butler "As the industrialized world undergoes daily transformations through the application of techno science to every aspect of life, science fiction has become an essential mode of imagining the horizons of possibility." - Istvan Csicsery-Ronay In this course students explore science fiction as expressed across media including film, television, music, contemporary art, literature, comics and games. Students will work in the medium(s) of their choice using the tactics of science fiction to investigate themes and topics including but not limited to: Utopia/Dystopia, Robots and A.I., Extraterrestrial Life, Speculative Design, Afrofuturism, Genomics, Transhumanism, Indigenous Futures, Posthumanism, Ecology, Climate Change, Space Travel, Time Travel and Alternative Histories.

60-499 Studio Independent Study

Fall and Spring

A tutorial studio in which an Art student works individually on a self-generated project under the supervision of a School of Art faculty member. Prior to enrolling in Independent Study, the student must complete an "Independent Study Proposal" form (available in the bins on the 3rd floor of CFA) which is signed by the faculty member and the Assistant Head of Academic Affairs of the School of Art. Prerequisite: Art Junior/Senior status and by instructor permission.

60-590 Internship

Fall and Spring

Art Internships are open to all BFA, BHA, BSA and BCSA Art students. Internships may take place with appropriate individuals or organizations within or outside of Carnegie Mellon University. The requirements for an internship are in the School of Art Handbook (available at the School of Art website). Prior to being enrolled for an internship, students must complete an Internship Proposal Form, which defines the goals of the internship. This form must be signed by their site supervisor and approved by the Assistant Head of the School of Art. Forms are available in the bins on the 3rd floor of CFA. Junior and Senior Art majors only.

School of Design

Eric Anderson, Interim Head
Location: Margaret Morrison Carnegie Hall 110
design.cmu.edu (<http://design.cmu.edu>)

Design at Carnegie Mellon

Design is the thoughtful activity that humanizes our environment through visual communication and the shaping of products that help us in our daily lives. Whether in magazines and books, posters and exhibitions, video and film, human-computer interactions, or any of the myriad of everyday products such as furniture, consumer goods, vehicles, or medical equipment, designers play an important role in shaping the form and content of our experience.

Designers are concerned with aesthetics, but they are equally concerned with serving people. This requires more than skill in the fine arts. It also requires knowledge about the needs, desires, expectations, and capabilities of human beings. It requires skills of observation and interpretation that help us understand the people that we want to serve. More than this, however, designers must also understand the technological issues that stand behind effective products. They must understand the materials, tools, and production processes of the modern world. An education in design is an education for the mind as well as the eye and hand.

The undergraduate program enables students to develop specialized skills in the areas of Product (Industrial) Design, Communication (Graphic) Design and Design for Environments (design for physical and digital environments), while providing them with a solid foundation in design studies. Students study systems thinking; the ability to see and solve problems at multiple levels of scale, and situate their work within larger social and environmental contexts.

The over-arching theme of the curricula is *design for interactions*, which acknowledges that 'ecologies' of products and communications often come together within complex physical *and* digital environments. Coursework balances making and theory with the integration of new, emergent technologies. Students are encouraged to explore the scope of design as well as the responsibility and ethics involved in the design of interactions between people, the built world, and the environment.

The curriculum is one that provides students with the ability to customize their degree: they may choose to specialize in one of three areas offered (Products, Communications, Environments), but also have the option of combining any two, to create a unique, interdisciplinary design degree.

The undergraduate curriculum also introduces students to three important areas of design focus: design for service, design for social innovation and transition design. These represent both new and established design approaches to framing and solving problems. In their senior year, students bring their disciplinary specialty (communications, products or environments) to projects that are situated within the areas of design for service and/or design for social innovation.

The School offers a Bachelor of Design with tracks in Communications, Products, or Environments.

Communications

The ability to communicate and shape meaning is one of the most powerful and ubiquitous forms of design in today's world. Students learn to design effective communications across a wide variety of media that *always* exist within complex webs of interactions between people, products, and environments. Areas of study include narrative and storytelling, information design, and a variety of analog and digital visualization techniques. Students develop the ability to identify specific audiences and communicate to them through effective visual, verbal and aural communications that educate, inform and delight.

They study the dynamic and 'emergent' characteristics of communications in a globally networked society where technologies and modes of individual and mass communication are constantly changing. Students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, prototyping and rigorous evaluation. Students develop the ability to identify and communicate to specific audiences through effective visual and verbal communications that educate, inform, delight and invite participation.

Products

Students learn to design products and their interactions within the context of human needs and they develop a deep understanding of the ways in which products shape behavior. Our curriculum acknowledges that no product exists in isolation—it is *always* part of a larger system comprised of people, communications and environments. Within the context of design for service, products exist as 'touchpoints' in a service ecology. For this reason, students learn systems thinking and engage in an iterative, multi-disciplinary and collaborative design process that involves research, observation, modeling/prototyping and rigorous evaluation.

Students are introduced to current production and manufacturing processes as well as sustainable approaches, such as cradle-to-cradle, lifecycle analysis and the use of new, more environmentally friendly materials. The School has a well-equipped analog and digital prototyping facility where students work with traditional materials such as wood and metal and learn to design and prototype using CAD software and 3D digital printers.

Environments

Students learn to design for complex environments that exist in the digital, physical and multi-modal realms. Most of the products and communications we interact with are situated within complex physical spaces (our homes, classrooms, places of business, shopping malls, even amusement parks). We also interact with complex online environments such as large websites, social networking and virtual reality environments. And increasingly we interact in 'smart' physical spaces with multi-modal communications in a combination of the analog and the digital.

In our curriculum, environments are seen as integrated and dynamic systems that require the design of interactions at multiple levels of scale. Students acquire a diverse set of skills that includes a deep understanding of spatial relationships, designing *with* and *for* emerging, multi-media technologies and an understanding of the cognitive challenges presented by multi-modal spaces.

Students who focus on the design of environments delve deep into systems thinking and systems dynamics and spend time learning to collaborate and lead within multi-disciplinary teams (solving large problems involving complex spaces almost always involves teams of people from different disciplines).

Design Minor Program

The School also offers a minor in Design for well-qualified students. Further information on the minor program is provided here (<https://design.cmu.edu/node/122/>).

The Design Curriculum

Minimum units required for Bachelor of Design

360

The design curriculum is for students who are interested in full-time undergraduate study leading to entry-level professional employment or advanced graduate study in the areas of Communication Design, Product Design, or Design for Environments. The first year is a period of discovery, where students explore studio projects and supporting courses in the ideas and methods of design practice as well as courses in design studies. The second and third years are a period of concentration and development primarily within the student's area(s) of specialization. The fourth year is a period of integration and advanced study, with studio projects involving teams of students from all areas of design. There are studio courses throughout all four years, supported by departmental electives in the ideas and methods of design practice and other courses in the history, theory, and criticism of design. In addition, the School also requires all students to take a substantial number of general education courses offered by other departments throughout the university. General education is an essential part of the education of a professional designer.

Foundation Year

In their first year, students are introduced to all three areas of design specialty: Product (Industrial), Communication (Graphic) and digital and physical Environments. Here, they explore these unique and complementary areas of design and gain a wide range of skill sets such as systems thinking,

iterative process, collaboration and visualization, and work in both two and three dimensional materials as well as digital media.

At the end of their first year, students are given the opportunity to begin to focus their interests in two of three design areas (products/communications/environments) and will eventually decide upon a single area of focus or a dual path of study.

This is the first-year curriculum for all design students.

First Year

Fall

| | | |
|--------|--------------------------|-----------|
| Studio | | Units |
| 51-101 | Studio: Survey of Design | 10 |
| | | 10 |

| | | |
|-------------------|-------------|-----------|
| Ideas and Methods | | Units |
| 51-121 | Visualizing | 10 |
| | | 10 |

| | | |
|----------------|---------------------------|-----------|
| Design Studies | | Units |
| 51-175 | Design Studies: Place | 5 |
| 51-177 | Design Studies: Histories | 5 |
| | | 10 |

| | | |
|-------------------|-----------------------------|-----------|
| General Education | | Units |
| 76-101 | Interpretation and Argument | 9 |
| 85-102 | Introduction to Psychology | 9 |
| or 85-211 | Cognitive Psychology | |
| or 85-241 | Social Psychology | |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| | | 21 |

Spring

| | | |
|--------|------------|-----------|
| Studio | | Units |
| 51-102 | Design Lab | 10 |
| | | 10 |

| | | |
|-------------------|------------------------------|-----------|
| Ideas and Methods | | Units |
| 51-122 | Collaborative Visualizing | 10 |
| 51-132 | Introduction to Photo Design | 10 |
| | | 20 |

| | | |
|----------------|----------------------------|-----------|
| Design Studies | | Units |
| 51-176 | Design Studies: Futures | 5 |
| 51-178 | Design Studies: Experience | 5 |
| | | 10 |

| | | |
|--|--|----------|
| Humanities & Social Sciences | | Units |
| One course in the Dietrich College of Humanities & Social Sciences | | 9 |

Second Year

Following the first-year program, students select two out of three areas of interest: Products[P], Communications[C], Environments[E]. In the fourth semester students select one of the two areas to study more deeply. Students investigate the relationships people form with designed artifacts and the roles that physical, visual, and digital forms play in our lives. They apply what they learn to the design of products, communications, and environments that facilitate interactions. Students are also required to take general education courses to gain a broad vision of many disciplines and fields of knowledge that are relevant to design.

Second Year

Fall

| | | |
|-----------|--|----------|
| Studio | | Units |
| 51-225 | Communications Studio I: Understanding Form & Context (Pick two) | 4.5, 4.5 |
| or 51-245 | Products Studio I: Understanding Form & Context | |
| or 51-265 | Environments Studio I: Understanding Form & Context | |

| | | |
|-------------------|---|----------|
| Ideas and Methods | | Units |
| 51-227 | Prototyping Lab I: Communications (Pick two corresponding labs) | 4.5, 4.5 |
| or 51-247 | Prototyping Lab I: Products | |
| or 51-267 | Prototyping Lab I: Environments | |
| 51-221 | Color for Communications, Products, Environments | 9 |
| or 51-229 | Digital Photographic Imaging | |
| or 51-242 | How Things Work: Mechanics and Electronics | |

| | | |
|----------------|--------------------------|-----------|
| Design Studies | | Units |
| 51-277 | Design Studies: Systems | 5 |
| 51-279 | Design Studies: Cultures | 5 |
| | | 10 |

| | | |
|-------------------|-------------------|----------|
| General Education | | Units |
| xx-xxx | Academic Elective | 9 |
| | | 9 |

Spring

| | | |
|-----------|---|----------|
| Studio | | Units |
| 51-228 | Communications Studio II: Designing Communications for Interactions | 9 |
| or 51-248 | Products Studio II: Designing Products for Interactions | |
| or 51-268 | Environments Studio II: Designing Environments for Interaction | |
| | | 9 |

| | | |
|-------------------|------------------------------------|----------|
| Ideas and Methods | | Units |
| 51-239 | Prototyping Lab II: Communications | 9 |
| or 51-249 | Prototyping Lab II: Products | |
| or 51-269 | Prototyping Lab II: Environments | |
| | | 9 |

| | | |
|----------------|----------------------------|-----------|
| Design Studies | | Units |
| 51-282 | Design Studies: Persuasion | 5 |
| 51-284 | Design Studies: Power | 5 |
| | | 10 |

| | | |
|-------------------|-------------------|-----------|
| General Education | | Units |
| xx-xxx | Academic Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 18 |

Third Year

In the fifth and sixth semesters, students may choose to continue their fourth semester area of focus, or they may choose to study their second area of study from the third semester. Students study how design functions at various levels of scale and degrees of complexity situated in specific contexts. They design products, communications, and environments that function as cohesive systems that live within the built and social worlds.

Third Year

Fall

| | | |
|-----------|--|-----------|
| Studio | | Units |
| 51-323 | Communications Studio III: Designing for Complex Communication Systems | 10 |
| or 51-343 | Products Studio III: Designing for Complex Products Systems | |
| or 51-363 | Environments Studio III: Designing for Complex Environment Systems | |
| | | 10 |

| | | |
|---|-----------------|-----------|
| Ideas and Methods (Select two Design Electives) | | Units |
| 51-xxx | Design Elective | 9 |
| 51-xxx | Design Elective | 9 |
| | | 18 |

| | | |
|-------------------|-------------------|-------|
| General Education | | Units |
| xx-xxx | Academic Elective | 9 |

| | | |
|---|---|-----------|
| xx-xxx | Free Elective | 9 |
| | | 18 |
| Spring | | |
| Studio | | Units |
| 51-330 | Communications Studio IV: Designing Communications for Social Systems | 10 |
| or 51-350 | Products Studio IV: Designing Products for Social Systems | |
| or 51-360 | Environments Studio IV: Designing Environments for Social Systems | |
| | | 10 |
| Ideas and Methods (Select two Design Electives) | | Units |
| 51-xxx | Design Elective | 9 |
| 51-xxx | Design Elective | 9 |
| General Education | | Units |
| xx-xxx | Academic Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 18 |

Fourth Year

In the senior year, students work to identify their next steps in professional practice, entrepreneurship, or in academia. They apply their design skills and knowledge to client-based and/or self-defined projects that focus on the design of services or social innovation.

The fall semester features the Design Research Studio, a semester-long project where students work in teams applying skill and knowledge learned in Products, Communications, and/or Environments. In the spring the Capstone Project challenges students to work independently on a semester-long project, deepening their understanding of service or social innovation design principles.

Fourth Year

| | | |
|--|---|-----------|
| Fall | | |
| Studio | | Units |
| 51-481 | Senior Design Studio | 12 |
| | | 12 |
| Ideas and Methods (Select one Design Elective) | | Units |
| 51-xxx | Design Elective | 9 |
| | | 9 |
| General Education | | Units |
| xx-xxx | Academic Elective | 9 |
| xx-xxx | Free Elective | 10 |
| | | 19 |
| Spring | | |
| Studio | | Units |
| 51-480 | Design Capstone Project: Service Design & Social Innovation | 12 |
| | | 12 |
| Ideas and Methods (Select one Design Elective) | | Units |
| 51-xxx | Design Elective | 9 |
| | | 9 |
| General Education | | Units |
| xx-xxx | Free Elective | 15 |
| | | 15 |

Other Requirements

General education courses should be selected from other departments throughout the university. Students are strongly advised to select a balanced set of general education electives-in addition to Interpretation and Argument, Humanities & Social Sciences Elective, and Introduction to Psychology - from three broad areas of study: arts and humanities, social and behavioral sciences, and natural sciences and engineering, including mathematics. While free electives may include studio courses in other departments, academic electives are non-studio (lecture) courses in other departments. Specific recommendations (and general requirements) for electives in all of these areas are available from advisors in the School of Design. The School places strong emphasis on the value of general education for personal growth as well as professional development. General education electives allow a student to obtain a minor in another department or program, such as business, human-computer interaction, IDEATE, engineering, professional and technical writing, or architecture.

Students may enroll for no more than 18 units of independent study courses, and no more than one independent study per semester. A minimum 3.0 GPA is required for independent study. Independent study is permitted only in the third and fourth years of the program. Proposals for independent study courses must be developed jointly by the student and a faculty advisor. Guidelines are available from the School.

A minimum GPA of 2.0 is required to maintain Professional Program status. Grades lower than "C" in required Design courses will result in academic probation, suspension, or drop from the School of Design.

Full-time students are required to enroll for a minimum of 36 units per semester, with 45 units required for expected degree progress (typically five courses per semester). The minimum number of units required for graduation in Design is 360.

Academic Standards

The design curriculum adheres closely to the fundamental professional entry-level standards established by the two leading national design organizations: the American Institute of Graphic Arts (AIGA) and the Industrial Designers Society of America (IDSA).

Applications

The School of Design accepts applications from students who are completing secondary education or who wish to transfer from within Carnegie Mellon University. The School also accepts applications from students who wish to transfer from other institutions. Students applying for the program are asked to submit a digital portfolio as evidence of design ability. This is considered in balance with evidence of academic ability, based on secondary school grades, SAT scores, class rank, and letters of recommendation. The School also accepts applications for the design minors program for a limited number of spaces. Details are available on the Design website.

Emeriti Faculty

JOSEPH M. BALLAY, Professor Emeritus - M.F.A., Carnegie Mellon University; Carnegie Mellon, 1970-2002-

DAN BOYARSKI, Professor Emeritus - M.F.A., Indiana University School for Design, Kunstgewerbeschule, Basel, Switzerland; Carnegie Mellon, 1982-2018-

CHARLEE MAE BRODSKY, Professor Emeritus - M.F.A., Yale University; Carnegie Mellon, 1978-2022-

THOMAS L. MERRIMAN, Teaching Professor Emeritus - B.F.A., Carnegie Mellon University; Carnegie Mellon, 1985-2020-

Faculty

ERIC ANDERSON, Professor & Interim Head - M.A., Ohio State University; Carnegie Mellon, 1998-

MARK BASKINGER, Professor - Ph.D, Royal Melbourne Institute of Technology; Carnegie Mellon, 2003-

JONATHAN CHAPMAN, Professor - Ph.D, University of Brighton; Carnegie Mellon, 2017-

WAYNE CHUNG, Professor - MID, University of the Arts; Carnegie Mellon, 2007-

DINA EL-ZANFALY, Assistant Professor – Ph.D, MIT; Carnegie Mellon, 2019–

KELSEY ELDER, Assistant Professor – M.F.A., Cranbrook Academy of Art; Carnegie Mellon, 2022–

BRUCE HANINGTON, Professor – M.E.Des., University of Calgary; Carnegie Mellon, 1998–

SUNKI HONG, Assistant Professor – M.F.A, Iowa State University; Carnegie Mellon, 2023–

KRISTIN HUGHES, Associate Professor – M.F.A., Virginia Commonwealth University; Carnegie Mellon, 2001–

TERRY IRWIN, Professor – M.S., Schumacher College; Carnegie Mellon, 2009–

HAEOYOUNG KIM, Assistant Professor – M.Des, Harvard University Graduate School of Design; Carnegie Mellon, 2023–

MARK MENTZER, Professor – B.F.A., Carnegie Mellon University; Carnegie Mellon, 1975–

DAPHNE PETERS, Assistant Teaching Professor – M.Des., Elisava, Escola Superior de Disseny; Carnegie Mellon, 2017–

STACIE ROHRBACH, Professor – M.GD, North Carolina State University; Carnegie Mellon, 2003–

DANIEL ROSENBERG, Assistant Professor – Ph.D, Massachusetts Institute of Technology; Carnegie Mellon, 2021–

PETER SCUPELLI, Associate Professor – MDes & Ph.D, Carnegie Mellon; Carnegie Mellon, 2011–

STEPHEN J. STADELMEIER, Associate Professor – M.S., Cornell University; Carnegie Mellon, 1977–

ANDREW TWIGG, Associate Teaching Professor – B.A., Allegheny College; Carnegie Mellon, 2014–

DYLAN VITONE, Associate Professor – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2004–

BRETT YASKO, Assistant Teaching Professor – B.A., The American University, Washington D.C.; Carnegie Mellon, 2019–

MATT ZYWICA, Associate Teaching Professor – B.F.A., University of Illinois; Carnegie Mellon, 2014–

Special Faculty

ASHLEY DEAL, Special Faculty – M.Des, Carnegie Mellon University; Carnegie Mellon, 2016–

GIDEON KOSSOFF, Special Faculty – Ph.D, University of Dundee, Scotland; Carnegie Mellon, 2017–

RAELYNN OLEARY, Special Faculty – M.Des, Carnegie Mellon University; Carnegie Mellon, 2016–

Courtesy Appointments

DARAGH BYRNE, Associate Teaching Professor – School of Architecture & the Integrated Innovation Institute,

JONATHAN CAGAN, George Tallman Ladd Professor of Mechanical Engineering – College of Engineering,

JODI FORLIZZI, Professor & Director – Human-Computer Interaction Institute,

STEFAN GRUBER, Associate Professor – School of Architecture,

SUGURU ISHIZAKI, Associate Professor of Rhetoric and Visual Design – Department of English,

DAVID S. KAUFER, Professor of English and Rhetoric – Department of English,

GOLAN LEVIN, Professor & Director of Frank Ratchye Studio for Creative Inquiry – School of Art,

PAUL PANGARO, Professor of Practice – Ph.D, Brunel University; Carnegie Mellon, 2022–

CAMERON TONKINWISE, Professor of Design Studies – University of Technology Sydney,

JOHN ZIMMERMAN, Associate Professor – Human-Computer Interaction Institute,

Adjuncts of Practice

VICTORIA CROWLEY, Independent Design Consultant

JOE DICEY, Letterpress Facilities Manager

KELSEY DUSENKA, Independent Design Consultant

ARTHI KRISHNASWAMI, RyeCatcher

HANNAH DU PLESSIS, Fit Associates

MARC RETTIG, Fit Associates

MYRNA ROSEN, Calligraphy Guild of Pittsburgh

Professional Affiliates

MATT BEALE, Principal, Daedalus Design

TIM CUNNINGHAM, Founder, Daedalus Design

CHERYL DAHLE, Founder, Flip Labs

School of Design Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

51-101 Studio: Survey of Design

Fall: 10 units

Students will conduct activities that will help them notice design in the world, investigate how it works, and describe their thinking about design, through photography, video capture, sketching, note-taking and modeling. They will work through projects in various ways as a means of 'testing-out' and reflecting on command design approaches. This course is for undergraduate design majors only.

51-102 Design Lab

Spring: 10 units

Introduce concepts and methods to familiarize students with a range of analog and digital modes of working across products, communications, and environments. Students will use desktop modeling and comping methods to familiarize them with a range of basic materials to build confidence in using and manipulating material to represent ideas. This course is for freshman Design majors only.
Prerequisite: 51-101

51-113 The Portrait

Intermittent: 3 units

The Portrait is a micro mini course

51-121 Visualizing

Fall: 10 units

This course introduces basic drawing and sketching techniques including figure-ground translation, 2 pt perspective construction, storyboarding for explanation, diagramming for clarification, field notation for recording through guided exercises, demonstrations, and short projects.

51-122 Collaborative Visualizing

Spring: 10 units

This course introduces frameworks of notational, exploratory and explanatory sketching using collaborative methods and exercises to cooperatively communicate design ideas. This course is for undergraduate design majors only.
Prerequisite: 51-121

51-132 Introduction to Photo Design

Spring: 10 units

Using a digital camera, students learn how to extend their 'seeing' with the camera, both in the world and in a shooting studio. Through shooting assignments student will understand how to: deconstruct image meaning and aesthetical choices, construction of photographic meaning and aesthetics, an understanding of color and how color delivers meaning, how a photographic studio works, proper digital photographic workflow and contemporary trends in photography. Intended for Design Majors, or permission of the instructor.
Prerequisite: 51-101

51-150 Design Your Life

Intermittent: 3 units

It is difficult to go on a life long journey without a plan or map. In the "Design your life" micro-course, students take on the most important design project: their own life. Students explore who they are, where they come from, and where they hope to go throughout their life. They describe their core values, what makes their life meaningful, and whom they hope to become in the future. While one's life is very personal, we use time-tested design methods to explore each person's future. We explore readings from: (1) George Lowenstein's Mattering Maps, (2) Elle Luna's "The Crossroads of Should and Must: Find and Follow Your Passion"; (3) Bill Burnett and Dave Evans approach to "Designing Your Life: How to Build a Well-Lived, Joyful Life"; (4) Verne Verne Wheelwright's person futures approach "It's YOUR Future...: Make it a Good One!", and Tony Fry's "Ontological Design". By the end of the micro-course each student will have made a plan for their future. They will be able to explain what matters to them and have charted a way forward. Most importantly, they will know how to rechart their life plans as unexpected events require them to adapt their plans.

51-171 Placing

Fall: 10 units

This course will explore the context in which students study design. Using primarily photography, students compare where they are from to the bioregion of the Ohio Valley of Western Pennsylvania and the history of the steel town, Pittsburgh. Students also learn about the modern Western emergence of design as a profession and discipline, and map the edges of current design practice by interacting with local professionals.

51-172 Systems

Spring: 9 units

This course explores how to understand complex phenomena by creating models of interrelations between components. Students learn soft systems diagramming as well as the systems thinking associated with ecologies, integrative science and socio-technical regimes. Students also learn how to see design as a way of making interventions into leverage points in a system in order to transform its functions.

51-173 Design Center: Human Experience in Design

Intermittent: 9 units

Design touches, and can profoundly affect, people's lives. But why? And how? This course begins with a broad definition of what design is (and can be). We'll see how design is about the process as much as it is about the final product. We'll look at how the end user interacts with what is designed. And we'll discuss how designers need to think beyond the actual artifact to what lies behind it. We'll touch on design theory, design practice, design responsibility and even some design history. And through a series of guest lectures, explorations of other designers' work, field trips, viewings, class discussions and projects, we'll try to determine just what design is and what designers do.

51-175 Design Studies: Place

Fall: 5 units

"Place" introduces you to place-based design thinking. It trains your senses to perceive all that is designed and sustains everyday human lifestyles, especially those infrastructures and services invisible to city dwellers in the built environment. In addition, you will recognize relations between natural and artificial worlds. Coursework covers methods to evaluate individual and collective environmental and social impact at a regional and local level through techniques that develop capacities to reveal dynamic relationships among elements.

51-176 Design Studies: Futures

Spring: 5 units

"Futures" frames design in a temporally-extended, systemic context. It offers essential perspectives, practices, and competencies that are increasingly called for as designers progress in their work and careers, and as the design field evolves to acknowledge its significant powers and responsibilities. You will explore numerous futures methods, which support designers through ideation and storytelling, problem-finding and framing, brief formulation, project coordination, and collaboration. Coursework includes engagement with readings and videos, hands-on creative workshops, and visual prototyping and sketching.

51-177 Design Studies: Histories

Fall: 5 units

"Histories" explores a plurality of design histories extending beyond the dominant, Anglo-European story of Design. Through a series of guest lectures, critical readings, and lively debates, you will expand your understanding of design as a "field," which evolves and changes over time in the context of broader technological, social, and philosophical developments; a tapestry woven of many threads, some more noticeable than others, but all relevant in their own way. Coursework includes authoring a well-historicized account of an influential designer, practice, or movement, and feature as part of a growing, online archive.

51-178 Design Studies: Experience

Spring: 5 units

Experience explores how design touches peoples lives, and shapes their materials and non-material worlds. Through a series of lectures, viewings, and class discussions, we'll try to determine just what design is and what designers can do. We will explore contrasting definitions of design, and get to know it as an experientially-rich process. We'll examine how users and audiences interact with what is designed, and debate the designers responsibility to consider what lies behind it. Coursework includes individual and team projects exploring design's role in shaping our experience of the world.

51-208 Research Methods

Spring: 4.5 units

Learn how to select, conduct, and develop appropriate research methods for understanding and discovering contextual information and behaviors of human participants.

51-215 Making Short Films

Intermittent: 3 units

The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn storyboard, plan, production, and post-production video. Equally importantly students will start to develop their own visual aesthetics in the creation of 1 short moving pictures. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of video as a means of narrative creation. This Micro course will run between 5-6 weeks. The instructor will fly into Doha for a short period of face-to-face classes, centered around a Saturday. Enrolled students should expect two 90-minute face-to-face classes during the week before or after this Saturday date, as well as four 90-minute evening (6-7:30 pm) video classes over the duration of the Micro course (typically two before the campus visit, and two after, although instructors can change this). Specific dates will be confirmed in the syllabus closer to fall semester.

51-221 Color for Communications, Products, Environments

Fall: 9 units

This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our visual design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer-term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.

Prerequisite: 51-122

51-223 Color for Communications & Products

All Semesters: 9 units

This course will explore the fundamentals of color through the implementation of various media as they apply to their use in communication and expression in design. While this course does not deal with color theory per se we will spend time on the causes and effects of color interaction, color contrasts, color harmonies and color strategies for the effective use of color in our design work. We will use both nature and man made constructs to discuss how color affects what we see and its effect on our visual world. Short exercises and longer-term projects will be the vehicles of our explorations. This course is for Sophomore Design Majors.

51-225 Communications Studio I: Understanding Form & Context

Fall: 4.5 units

Giving form to messages and information using type, color, and images will be the focus of this introductory studio in Communication Design. Understanding the connection between content, intent, and form will be the goal of every project and exercise. Principles of hierarchy, chunking, sequence, clarity, and visual voice will guide work for the screen and the printed page, in dynamic and static forms.

Prerequisite: 51-122

51-227 Prototyping Lab I: Communications

Fall: 4.5 units

Learn the core methods and tools of visual communication design, with a focus on Adobe CC: particularly InDesign, Illustrator, Photoshop, Prototyping tools, and After Effects. The learning of software ideally will align with the activities conducted in the Communications Studio. This is a requirement for Design sophomores studying Communications.

51-228 Communications Studio II: Designing Communications for Interactions

Spring: 9 units

At its most basic level, Communication Design conveys ideas and translates concepts into visual form. This form needs to be such that an audience will want to look, engage and (hopefully) learn. To get there, you will need to develop your process. Your own unique path. This is not easily done. It's also not prescriptive. There isn't one defined straight path. It's more like a wild and crazy zig-zag. A goal of this course is for you to give yourself permission to wander beyond the areas you're comfortable with to not be afraid of stretching beyond where you think you may be capable. And to develop your own individual process. We will work on a series of four print-based and interactive projects. You will broaden your understanding of color, scale, hierarchy, typography, grid systems and how to make things that both communicate and resonate with your audience. Everything we design is an opportunity to make work that is compelling, memorable and moving. This is a required course for all SoD Sophomores who are pursuing the Communications track.

Prerequisite: 51-225

51-229 Digital Photographic Imaging

Fall: 9 units

The objective of this course is to provide students with a practical, technical and theoretical foundation in digital imaging. The primary software for this course is Adobe Photoshop, with which students will explore construction, combination, manipulation, input, and output of image as a means of narrative creation. Through project critique and other discussion, we will also consider the aesthetic and political implications of the emergence of this and other new electronic imaging technologies.

51-231 Design Center: Calligraphy I

All Semesters: 9 units

Working with pure unadorned Roman letterforms, this course introduces students to the theory and practice of hand-generated letters, employing a variety of mark-making tools. This course provides an in-depth understanding of the basic principles and techniques of the art of formal writing. Rhythm, texture and composition are achieved through routine, elementary exercises using geometric forms, demanding concentration and manual discipline with the development of hand-eye coordination. The function, use, and harmonious sequencing of letterforms is taught through weekly projects. Awareness of rhythm, texture and letterform structure is achieved through routine exercises. Drills, demonstrations, discussions, individual and class critiques are on-going. Additional related topics and activities introduced in class include books: binding and design. A brief introduction to the historical development of our Western alphabet is provided through film, slides, demonstrations, with discussion of twentieth-century type designs. Students also gain exposure to letter vocabulary, paleography, monographs, words and punctuation, classical page design, publication design-past and present, and calligraphy's role in design today. Thinking with hands and eyes, the manual placement and spacing of letters practiced in this course awakens sensitivity and judgment in the designer.

51-232 Design Center: Calligraphy II

All Semesters: 9 units

This course serves as a continuation and deeper investigation of topics explored in Calligraphy I, where students tackle advanced problems in calligraphy and lettering. The introduction of new hands is to be decided by the student and instructor. Prerequisites: 51231

Prerequisite: 51-231

51-236 Information Design

Fall and Spring: 9 units

This studio course focuses on teaching a basic visual design process from ethnographic research through ideation to finished artifact. Students will work individually and in teams to gain proficiency in applying specific design techniques to information design challenges. Students will attend lectures to gain new perspectives, engage in projects to learn through making, conduct readings to balance theory and practice, participate in critiques to verbalize their views and consider alternate perspectives, join in discussions to develop shared understanding, give presentations to communicate their thinking, and complete tutorials and learn software for additional insight.

51-239 Prototyping Lab II: Communications

Spring: 9 units

Program simple websites as a means of learning basic HTML 5.0 and CSS; prepare documents for digital and print production using Adobe InDesign, Illustrator, Acrobat; learn basics of UX prototyping
Prerequisite: 51-227

51-240 Design, Brands, & Futures: Service Design Approaches and Pivots

Intermittent: 3 units

This micro will introduce students to service design and help students develop skillsets and knowledge that will serve them in their particular area of study. This includes ways of analyzing existing businesses and services, empathizing with multiple stakeholders in a complex system, and developing ideas for ways that existing businesses and services could adapt and evolve to emerge from the pandemic more resilient. Students will also use the power of storytelling to develop presentations that communicate their ideas in compelling ways.

51-241 How People Work

Fall: 9 units

51241 How People Work: Human Factors (ID/CD Lab I) This course is a general introduction to the field of human-centered design and applied human factors. It centers on the understanding of physical, cognitive, and emotional human needs and desires, including methods employed to acquire this information and translate it into useful criteria for the design and evaluation of products. Lecture, discussion, lab exercises, and projects are employed. Required of all sophomore design students. Others admitted by permission of instructor only.

51-242 How Things Work: Mechanics and Electronics

Intermittent: 9 units

This course investigates the basic principles of mechanics and electronics. Through the combination of lectures, investigations, and lab experiments, students develop simplified representations of complex systems. The skills of freehand drawing, mechanical drawing and three-dimensional models are employed and developed during the project sequence. Instructor permission required for non-Design majors.

51-245 Products Studio I: Understanding Form & Context

Fall: 4.5 units

This mini-semester course takes students through a progression of exercises and projects that investigate how object forms can relate to people through reasons of looks, feel, function, make, and preference. The understanding of context plays a role as the system of internal and external factors and conditions that cause people to interact a particular way through how they recognize, handle, move, and perform activity with the form and material of an object. Drawing and physical modeling become essential tools for the planning, development, and communication of these ideas.
Prerequisite: 51-102

51-247 Prototyping Lab I: Products

Fall: 4.5 units

The course will consist of introductions, demonstrations and solutions to introductory aspects of SolidWorks. Forming foundation skills in CAD-based communication and problem solving will be emphasized.

51-248 Products Studio II: Designing Products for Interactions

Spring: 9 units

This course provides essential methodologies for the conceiving, planning, and realization of three dimensional objects and is coordinated with the Prototyping Lab 2 course to provide for an experiential understanding of the relationship between designing and making. From an operational standpoint, this course gives primacy to the material object to probe its characteristics more deeply and to critically explore an object's role as part of the assemblage of interaction and experience. Students will develop three-dimensional visual literacy, emphasizing the relationship between form factors and overall visual/physical impact in service of supporting human interactions. Through a hands-on approach, this course covers the "how" and the "why" of product/object development through the primary lens of "design for interactions."
Prerequisite: 51-245

51-249 Prototyping Lab II: Products

Spring: 9 units

This course introduces students to high fidelity modeling techniques through a series of machines, processes, and or methods to simulate desired form, scale, and proportions.
Prerequisite: 51-247

51-251 Digital Prototyping

Fall: 4.5 units

A half-semester laboratory mini-course introducing 3D modeling software. Each class meeting consists of an introduction to and demonstration of specific aspects and functions of SolidWorks software. At the end of each class session, work related to the covered topic(s) will be assigned for completion by the next class meeting. This course is a requirement for all ID majors. Instructor permission required for non-ID majors.

51-252 Design, Brands, and Futures: Design Thinking for Sustainable Change

Intermittent: 3 units

Design Thinking is a powerful process that expands creative potential and drives sustainable innovation. Work with CMU Design faculty and acquire powerful creative tools that you can immediately put into practice as an agent of sustainable change.

51-256 Design, Brands, and Futures: Designing Product and Service Identities

Intermittent: 3 units

In this course, students and I will delve into investigating social and cultural patterns both historical and contemporary which guide effective approaches to branding products and services. For example, what helps people feel happy, accomplished, confident? What do they wear? What do they eat? Where do they gather? What do they do for enjoyment? What do they value? Students will work to align their discoveries to the graphic forms, colors, typography, and taglines that they create as part of a comprehensive branding strategy, which they will base on a product or service of their own choosing. Students will achieve these goals by engaging in a creative process where they will sketch, iterate, test, and refine graphic symbols and typography using conventional paper and pencils as well as Adobe Illustrator. Throughout the course, we'll also discuss communication trends and the role technology plays in shaping how and where brands appear in our everyday lives. Based on what they learn, students will propose various forms that their graphic symbols may take and brainstorm contexts in which they may appear. For example, how might their concepts appear in motion in a video viewed on a phone, or on the side of a food truck? Through this process students will explore the affordances and limitations of various mediums and contexts and test the flexibility of the branding systems they create.

51-257 Introduction to Computing for Creative Practices

Intermittent: 10 units

This course is an introduction to Java programming for designers, architects, artists and other visual thinkers, using the popular "Processing" Java toolkit for interactive graphics. Intended for students with little or no prior programming experience, the course uses interaction and visualization as a gateway for learning the traditional programming constructs and the fundamental algorithms typically found in a first course in programming. Students will become familiar with essential programming concepts (types, variables, control, user input, arrays, files, and objects) through the development of interactive games, information visualizations, and computationally-generated forms. Because of limited space, only Design majors may take this course. Students following an IDEATE concentration or minor should register for 15-104.

51-261 Design Center: Communication & Digital Design Fundamentals

Fall: 9 units

A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required. This course (or 51262) is required for Design minors. Section W - Qatar campus only

51-262 Design Center: CD Fundamentals: Design for Interactions for Communications

Spring: 9 units

A one-semester course that introduces non-majors to the field of communication design. Through studio projects, lectures, and demonstrations, students become familiar with the visual and verbal language of communication designers, the design process, and the communicative value of word and image. Macintosh proficiency required.

51-264 Design Center: Product Design Fundamentals: Design for Interactions for Products

Spring: 9 units

In this one-semester studio-like course non-majors are introduced to product design from the product designer's point of view. Through studio projects, lectures, and discussions, students will learn approaches to defining and visualizing product concepts for mass production. Case histories and the analysis of existing products will supplement hands-on experience in developing product concepts. This course is required for all Design minors.

51-265 Environments Studio I: Understanding Form & Context

Fall: 4.5 units

This mini course will teach you the elemental strategies for designing meaningful, narrative-driven spaces and experiences. Through projects looking at the world as it is today and speculatively 10 years in the future, you will develop your ability to think through the relationship between time, space, scale, materials, and technology. You will use what you learn in 51-267 (Prototyping Lab 1: Environments) to develop both analog and digital high-fidelity artifacts that communicate the interactive experiences you have designed. This course is a requirement for Design students who wish to study Environments during their time at SoD.

Prerequisite: 51-102

51-267 Prototyping Lab I: Environments

Fall: 4.5 units

This mini course will provide you with practical skills to aid you in the design of interactions in environments and how to communicate your ideas to others. These include low-fi prototyping, rapid making, high-fidelity scale models, digital 3D modeling, typography in space, UI/UX strategies, augmented reality (AR) prototyping, basic electronic prototyping, and the development of concept videos. Building upon what was learned in your first year, you will continue to use Adobe Photoshop and Illustrator, while also being introduced to Adobe AfterEffects, Aero, and SketchUp. This course is a requirement for Design students who wish to study Environments during their time at SoD.

Prerequisite: 51-102

51-268 Environments Studio II: Designing Environments for Interaction

Spring: 9 units

Introduce students to the concept of resonant environments that provide meaningful physical and virtual experiences; utilize a range and combination of analog and digital tools for high fidelity output.

Prerequisite: 51-265

51-269 Prototyping Lab II: Environments

Spring: 9 units

Explore simple reactive and interactive programming as a means to support virtual and hybrid digital/physical environments.

Prerequisite: 51-267

51-271 How People Work

Fall: 9 units

Introduction to human-centered principles of design, including physical, cognitive, and emotional human factors. Capacities and limitations of people affected by design are learned through the study of known principles and user research. The course is delivered through a series of combined lectures, readings, hands-on lab activities, and a team project applying human-centered field research methods and design.

51-272 Cultures

Spring: 4.5 units

Explore the sociotechnical aspects of the many identity based differences between people. These differences may be not only cultural, but also related to gender, age, class, race etc. The course will survey critical theories that are useful for understanding how difference both constructs, and is constructed, by systems, practices and things. Students will also explore different frameworks and strategies for exploring questions of difference, and to think critically around the ethical and political implications for design interventions.

51-277 Design Studies: Systems

Fall: 5 units

"Systems" prepares you to design for, and within, complex systems. You will make use of systems theory and experiment with systems-thinking techniques to interpret and illustrate how ecological, social, and cultural systems operate at different levels of scale. You will also learn to identify leverage points within a system, and design ways to intervene that creates openings for norms, behaviors, attitudes, and habits. Coursework includes exposure to theoretical frameworks, analysis of case studies, and complexity mapping projects to analyze and represent the world from scalar and systemic perspectives.

51-279 Design Studies: Cultures

Fall: 5 units

"Cultures" immerses you in ways in which societies shape design, and how design shapes societies in return, rooted in historical and philosophical origins of identities and cultures. We will explore various aspects of human difference and relate them to the designed, material worlds we inhabit. Coursework involves reflective practices to connect theoretical, personal, and contextual understandings of the themes exposed, to explore meaning, purpose, and values that represent you as a person and as a designer.

51-282 Design Studies: Persuasion

Spring: 5 units

"Persuasion" develops your capacity to put across your message, to get other people to understand you, to value your work, and to want to work with you skills that will be central to your career, both inside and outside of design. Understanding what persuades you and others how we are influenced by other people, by media, by technology, by our environment, by design is a critical skill to develop in better understanding yourself, your design practice, those around you, and society more widely. Coursework includes a series of persuasive, exploratory exercises including filmmaking and exhibition of speculative work.

51-284 Design Studies: Power

Spring: 5 units

"Power" explores the concepts of politics, the political, and the powers that intertwine with design. You will delve into the mesh conformed by plural forms of knowledge, wisdom, power, and designs. A deepening into matters of ideology allows us to think critically about how designed artifacts are the embodiment of ideology; having the power to influence what people think, and shape their aspirations, desires, and values. You will be exposed to emerging design practices and theories that harness the power of design for social change with sociocultural and ecological mindsets. Coursework includes facilitation of activities for the collective analysis of topics at the intersection of design and power.

51-317 Publication

Intermittent: 9 units

For this course you will arrive on Day 1 with a story that you want to tell. You will then spend the semester iterating, designing, producing, publishing and, finally, putting your publication out into the world in a compelling, memorable and designerly way. Your publication can take the form of a substantial book, a series of smaller booklets or zines, a film, an interactive experience, a piece of public art, a combination of two or more of these or something else entirely. As long as it can be disseminated beyond the classroom and campus. This course will only work for those who have an idea. You must come into this course with a firm grasp of the story you want to tell, how you want to tell it and who you want to tell it to. There is only one project for this course. It will be robust and multi-faceted and you will only have 13 weeks to make it. So you need to be ready to go from the start. The first class will be dedicated to hearing your pitch for what you want to do. It will then be determined if you should stay on the roster.

51-318 Design Center: Community Rituals & Civic Ceremony: Building immersive experiences

Intermittent: 4.5 units

This course combines social games and physical techniques from public theatre with contemporary design practices in the immersive experience industry to examine group rituals and civic ceremonies from ancient Mesopotamian, Mesoamerican, and Asian traditions. Participants will create and perform original civic ceremonies that harness group energy to "enchant" their surroundings, their belongings, and each other.

51-319 Digital Photography in the Real World

Intermittent: 4.5 units

DIGITAL PHOTOGRAPHY IN THE REAL WORLD Photographers are active observers. They look until they see what they want others to see -then they compose and click the shutter. In this course students will walk streets with their cameras. They will learn how to use their cameras to better understand what they believe is important, beautiful, and/or intriguing in the world. They will also learn how to communicate their imagery to others through screen-based and print output. Assignments range from accurately describing reality, to showing aspects of life that should be improved, to making images for purely aesthetic reasons. There are two main goals to this course: learning the fundamentals of operating a digital camera and producing digital output; and, learning to become better 'seers' in the world. Students must own a camera but no prior photographic experience is necessary.

51-321 Design Center: Photographic Narrative

Intermittent: 9 units

Most photographs tell stories. We see photographs in newspapers, magazines, snapshot albums, on the web, in books, and in posters. In these contexts photographs often work with words to convey meaning, whether they are shown with captions, news stories, or just with titles. Photographs can work without words, too, to create purely visual narratives. In this course, students will make a photo narrative and determine how it will be seen. Students may make photo books, for example, or decide that their images will be seen digitally on screen. While students are making photographs, we will explore the rich traditions of photographic story-telling that range from the world-oriented work of photo-journalist W. Eugene Smith to the documentarians such as Walker Evans, Nicholas Nixon, and Alec Soth. We will look at photographers, too, who construct fictional worlds, such as Duane Michals, Cindy Sherman, and Gregory Crewdson. As students make their own narratives, we will look at the interplay between words and photographic images; how images are paced and scaled to create rhythm; how photographs are sequenced to tell stories; and other formal elements involved in creating visual narratives. 12-15 students. Prerequisite-a college level photography course.

51-322 Advanced Digital Imaging

Intermittent: 4.5 units

Building on the technical skills and methods of communicating narrative learned in Digital Imaging Advanced Digital Imaging takes communication to the next level of resolution with particular concern in artifact creation. Students explore historical and groundbreaking means of content delivery.

51-323 Communications Studio III: Designing for Complex Communication Systems

Fall: 10 units

Gain a greater understanding of how to craft communications that resonate with specific people by researching topics/audiences/context, by developing/iterating/testing concepts, and by investigating deeply the nuances of typographic form/image/sequencing of interactions; learn how to craft graphic form to express ideas that are not dependent on the reading of words themselves; continue to develop communication systems
Prerequisites: 51-228 and 51-225

51-324 Basic 3D Prototyping

Spring: 4.5 units

A half-semester laboratory mini-course introducing a range of materials, methods, and workshop techniques by which designers prototype designs in three dimensions. Basic competence in shop techniques is established by bringing to realization a series of simple artifacts. Studio and model shop tools are required; lab fee. Instructor permission required for non-Design majors.

51-326 Communication Systems Design for Social Equity

Intermittent: 9 units

This course will take a systems approach to understanding issues related to social equity and justice and will explore the creation of effective communication strategies for specific audiences across a range of analog and digital platforms. In this class students will explore and discuss the meaning of "social equity and justice" and explore its many facets through 1) assigned readings and discussions; 2) research on the problem and the stakeholders affected by it; 3) and the design of a communication system. A review of communication design from historic social equity movements will introduce the course. Students will work in teams to select a social justice issue, and map both the problem and the stakeholder groups affected by it in order to identify target audiences for the communication system. Over the course of the semester, students will formulate content and messaging for use in a range of communications that work together as a system such as brief tweets and messages + images for online platforms, concepts for apps, brief videos as well as print applications such as posters, brochures etc. The final result will be a multi-pronged campaign to raise awareness and motivate action with respect to a social justice/equity problem. Class will meet once a week for 2 hours and 50 minutes. Students will be asked to work in Miro and other online collaborative platforms. This course will be offered remotely.

51-327 Design Center: Introduction to Web Design

Fall: 9 units

This class will introduce the basics of designing and building websites, the fundamentals of HTML5 and CSS3, and responsive design approaches to assist students in creating semantically sound web pages that can be viewed across a variety of platforms, devices and browsers. The class will help students understand the constraints and advantages of working with the web, with this course focused on technically pragmatic solutions for making websites. Students will also be exposed to content management systems and topics such as responsive web design, research, and information architecture. Upon completion, students will be capable of designing, creating, launching and managing their own web sites. Your own laptop is required, with the following software installed: Adobe CS6 or later, as well as other open-sourced software. This course is for Design Majors only, or by special permission of the instructor.

51-328 Design Center: Design for Digital Systems

Intermittent: 9 units

Through tools and methods of user experience research and ideation, Design for Digital Systems uses web-based technologies to create functional prototypes for digital systems. Through demos, exercises, and a team-based trans-disciplinary project, students will use design thinking, industry-standard UX software, and code to identify, propose, and generate novel ideas for user problems. Students will learn advanced HTML and CSS, along with basics of database-driven web platforms using server-side technologies such as PHP and databases. The course is focused on screen-based interactions, but not exclusively so; it considers what technologies are viable today while leaning into the future to solve problems. Experience with HTML, CSS, and JavaScript is recommended but not required. This course replaces 51328 and 51828 Advanced Web Design. There may be a lab fee for non-design students.

51-330 Communications Studio IV: Designing Communications for Social Systems

Spring: 10 units

As the final course in a sequence of studio courses for Communication Design majors, this one builds on everything learned previously. Apply skills/knowledge learned in researching, developing, evaluating, refining communications to multi-faceted communication challenges that warrant the design of multiple communication pieces that span diverse mediums (in print and digital platforms) and function as a system; learn how to design for futuring (parts of the system yet to be determined) and for co-design where parts of the system are made for growth through contributions from audiences. This course is required of Communication Design majors in the School of Design.

Prerequisite: 51-323

51-331 Design Center: Advanced Calligraphy I

All Semesters: 9 units

This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy I.) Students may take one of two directions in the course. (1) Enlarging their repertoire of scripts, contemporary or traditional, for use in limited areas of work such as book or display work, or (2) Concentrating on more intensive problem solving using a limited repertoire of scripts such as Roman, Italic, Sans Serif.

Prerequisites: 51232

Prerequisite: 51-232

51-332 Design Center: Advanced Calligraphy II

All Semesters: 9 units

This course serves a continuation of study in the discipline of calligraphy. (It meets at the same time as Calligraphy II.) Students are encouraged to tackle advanced problems or work with the instructor to determine new directions of study. Prerequisites: 51331
Prerequisite: 51-331

51-333 Design Center: Collaboration by Design

Intermittent: 9 units

In Collaboration by Design, we'll be working on improving the ways we collaborate. Through this hybrid seminar/project-based studio, we'll explore ideas to improve collaboration in formal and informal contexts, along with intra-, inter-, multi-, and trans-disciplinary settings. We'll be exploring how issues such as personal values and goals, intimacy and independence, team dynamics, constructive criticism, and others affect the way we work together. Students can expect reading assignments, class discussion, informal (low stakes) writing projects and presentations, and team-based exercises and projects in which we share and apply our learning and develop ideas. Note: students taking this course will help set the topics and curricular trajectory for the course in collaboration with the instructor, so from day one we'll start the work of defining what we'll do, together.

51-336 The Non-Selfie

Intermittent: 9 units

The Non-Selfie: using the camera to record, probe, and understand one's own and another's behavior This course is the opposite of the selfie, but it uses the camera to record human behavior, both your own and another's. Designers need to be good human observers in order to design for human needs. Designers also need empathy. This course aims to deepen sensitivity to others by first better understanding ourselves. Informed by Manfred Max-Neef's classification of fundamental needs and other relevant materials, we will create two in-depth photo-essays, the first being a study of ourselves, the second being a study of someone who is unfamiliar to us. In the first half of this course, while looking at the tradition of self-portraiture in photography and other media, we will be making in-depth photographic stories of ourselves. In addition to photographs, we may make scans of objects, include personal artifacts and anything else that may contribute to building an in-depth self-portrait. In the second part of the semester, we will apply what we learned to a person who we do not know, in hopes of bringing new insights and methods to understanding for another. In addition, we will look at the rich literature that exists in documentary photography about representing "the other." By the end of the semester, each student's work will be made into a hand-made Japanese stab book of two volumes: a volume on oneself, and one on another. The skills learned in this course are immediately relevant to becoming a good designer. Digital camera is necessary, and knowledge of camera operation, Photoshop and InDesign is helpful.

51-338 Documentary Photography

Intermittent: 4.5 units

Documentary Photography: the Social and Built Landscape Documentary photography explores issues, often social, humanistic and/or political, in man-made culture. This course examines the work of nineteenth, twentieth, and twenty-first century documentarians while students photographically investigate their own topics. Among the many ethical areas of a documentarian's concern, the course examines (through looking at the documentary tradition and through the student's own work) the following: the photographer's relationship to the subject; the choices involved in representing the subject; the act of selectivity in framing the subject; the reasons for making documentary photographs; the intended audience for documentary photography; and the appropriate final display of the photographs? Extensive shooting, printing, and library research. Prerequisite: A beginning photography course, or by the permission of the instructor.

51-341 How Things are Made

Fall: 9 units

This course will provide a breadth of knowledge for current manufacturing, materials, and processes encountered in the industrial design field. There will be an emphasis on actual production/manufacture methods and not rapid prototyping methods. The class will consist of various lectures, media, electronic tools, and on-site visits to enable an understanding of how mass production affects design and design decisions. Industrial Design Juniors and amp; Seniors or permission of the instructor.

51-343 Products Studio III: Designing for Complex Products Systems

Fall: 10 units

This course provides a framework for understanding core practices of the product design profession by placing it in relation to other disciplines and their influences on mass manufacture of goods; students will use a design process to identify problem/s, map a process in which tangible artifacts are made to learn more about the interaction between object, person, space, and context Prerequisites: 51-245 and 51-248
Prerequisites: 51-245 and 51-248

51-344 Advanced Digital Prototyping

Spring: 6 units

This course is an advanced course using SolidWorks computer modeling. It is a prerequisite for Production Prototyping. This course is intended for undergraduate Design majors.
Prerequisites: 51-245 or 51-324 or 51-249

51-346 Production Prototyping

Spring: 6 units

This course is the 2nd half of Advanced Digital Prototyping, using your work in SolidWorks to produce hard models. This course is for undergraduate Design majors.
Prerequisites: 51-324 or 51-249

51-347 Drawing from Nature

Intermittent: 9 units

Drawing From Nature This course is about observing and making images of things growing, crawling, flying, swimming etc. Observations will be made firsthand in the field, supported with relevant research in topic areas with the aim of deepening personal understanding of all things biological. Issue surrounding natural forms such as behavior, locomotion, adaptation, the environment and systems will also be investigated. We will work in tandem on refining our abilities in communicating what we discover through the process of drawing. A variety of visualization methods will be covered i.e. analytical drawing, visual notes, and diagramming to name a few. We will be using a variety of basic drawing and digital media to develop our work as we uncover aspects of form, structure and surface. Guest speakers will present work they have done in areas such as botany, biology, and environmental studies to name a few. A majority of the work will be done in the field and will then be developed in the studio. A final project will be assigned that will challenge you to develop a concept along with a compelling form(s) that communicates what you have uncovered about nature to a variety of audiences. This course builds on your experiences from First Year drawing and introduces several more advanced visualization methods. This course is intended for Junior and Senior Design Majors.

51-349 Visual Notation/Journaling

Intermittent: 9 units

Visual notation is the graphic equivalent of taking written notes. While the camera is a valuable and at times indispensable tool for recording what we see, the camera cannot make visible mental concepts. Nor can it discover and display underlying structures, create hierarchies, explain organizational schema or concepts that are not easily seen or understood. This course is about making visual notes in order to become fluent in your abilities to observe, record and interpret. Through daily entries in a journal you will work in several content areas i.e. mapping, natural and built environments and systems to name a few. A good portion of the work in this class will be conducted in the field using the resources available to us such as the museum, zoo and architectural sites. You will also be challenged to incorporate your notes as tools for communicating design concepts, implementing project development and presentations. The course will rely on the use of a variety of simple drawing tools and electronic media. Several visualization methods will be introduced and the work will build on the drawing experiences from First Year drawing. This course is intended for Junior and Senior Design Majors.

51-350 Products Studio IV: Designing Products for Social Systems

Spring: 10 units

This course challenges students to build their own design and research process to identify and frame the scale and scope of a problem/opportunity, and place it in relation to the wider system (social, cultural contexts); projects will require synthesizing a range of inputs to develop proposals for future working and living.
Prerequisite: 51-343

51-352 Product Design: Influences on and trends within: 1900 to Present

Intermittent: 4.5 units

A personal perspective on some of the prominent influences and trends in the field of product design since its inception as a recognized commercial discipline, some 100 years ago. The growth of mass-production, its development from craft-based making origins, the impact of technological developments, two world wars, the presence of visual media and advertising, and other cultural waves and trends all show themselves in the products we design, desire, produce and inspire us. Through a series of talks, readings, presentations and a few guest speakers, the class will take a less-than-formal approach to looking at how we got from where we were then to where we are now. There will be discussions, writings, and a visual, notated journal to track your thinking, express your reactions, and thoughts, and the beginnings of a visual archive to take with you after the course ends. An interest in product as a window into cultural thinking is recommended, but not required. Writing, sketching, and searching skills are recommended for participants. Assessment is based on participation, engagement, and the building of a personal archive. 15 students maximum. Preference given to P track undergraduates

51-355 Experimental Sketching

Intermittent: 4.5 units

Experimental Forms of Sketching fall 2011 Advancing design drawing philosophy and application This 7 week mini course seeks to expand our experiences with interpreting forms of drawing quality within the process of sketching. This approach will explore semantics of rendering with mixed media, sensitivity of representational perspective, form building, and sequence evolution, within drawing developments that stimulate emotional connections with a viewer. Through exploring and testing variables, we will use the nature of drawing behavior processes to expand the interpretive significance of abstract idea forms. These "drawing idea forms" will be represented throughout a range of abstract levels from literal to highly figurative. Interpretations will derive from a variety of themes involving design, life, and nature and expressed on paper as objects, scenes, and story persuasions.

51-357 Stuff That's Optional: People at Play

Intermittent: 9 units

Stuff that's optional: People at play Unlike our necessary work that provides sustenance for self and dependants, our recreation is optional and chosen. Products that support recreation are, likewise, an option. Soccer balls, kayaks, daypacks, fly reels, chess sets, running shoes; for that matter, the entire recreational industry is based on election. Our lives are better off for it; play is good for us. In this studio/ project course we will investigate play as an aspect of human endeavor. There are readings, discussions, and sessions aimed at gaining an understanding of the field. We will then respond by searching out and framing design opportunities, ideate and propose, refine and test. We will make stuff as teams and individuals that help us further define what it means to be humans at play. This course is intended for Junior and Senior Design Majors.

51-359 Tools for UX Design

Intermittent: 9 units

The course intent is to develop appropriate user experience of tools and technology for a projected time frame or context of use. The need to understand people's stories, their lives, and how they want to live determines what interfaces, products, and systems should be developed. Student teams will work together to create appropriate user interactions and experiences which are supported by the design of tools and/or technology. This integrated course will utilize rapid prototyping as the basis for the creation of these proposed tools and products. This course is intended for junior, senior, graduate level students, Non-Disclosure Agreement and other legal agreements may be part of the requirements. Proficiency in one or more of these visualization methods: freehand sketching, computer visualization in 2D graphics, motion graphics and/or 3D solid or surface modeling. By Instructor Approval if NOT in Design. Please forward statement of intent to Instructor.

51-360 Environments Studio IV: Designing Environments for Social Systems

Spring: 10 units

Develop high fidelity proposals and demonstrations of multi-modal hybridized physical-digital environments based on rich information content and principles of user experience design.
Prerequisite: 51-363

51-361 HyperSENSE: Augmenting Human Experience in Environments

Intermittent: 9 units

We make sense of the world using our bodies, and just as we shape the environments around us, they also shape our experiences and senses. We will look in this course at how we can create physical and digital interactions that bridge the gap between humans and built environments to augment our senses. We will explore and introduce new roles of computational design and making in embodied sense-making, including human perception and cognition. We will apply methods and practices that form the basis for embodied interaction design. We will create projects that materialize these interactions using research-through-design and iterative design methods. Students choose the themes for their final projects or join an ongoing research project. Students in this class will work in groups to create installations in space controlled by human actions or wearable pieces that augment the body. Course deliverables include participating in reading discussions, a main project, and a publishable paper documenting the theoretical approach, creative process and findings. The instructors will help students publish their papers or pictorial in upcoming design conferences if students ask for help. Some possible themes for these projects could be: An installation that materializes a human presence in a remote space; a remote collaboration work tool or a wearable piece that enhances a certain human sense, and/or alters the perception of a specific space.

Course Website: <https://embodiedcomputations.org/teaching> (<https://embodiedcomputations.org/teaching/>)

51-362 Environmental Typography: Experiments in Space, Place & Identity

Intermittent: 9 units

This course explores the creative opportunities for typography in the physical environment. Through both individual and team projects, we experiment with dimensionality, material, color, and form. Design experiences that consider scale, interaction, and experimental type. Learn theories, concepts, and strategies related to wayfinding. And lastly, give form to identities through color, material, form, and typographic systems.

51-363 Environments Studio III: Designing for Complex Environment Systems

Fall: 10 units

Provide a framework and tools for designing for environments using experience design methods as a means to address the plurality of digital/ physical hybrid environments

Prerequisites: 51-268 and 51-265

51-364 Drawing Spaces

Intermittent: 9 units

The natural and built environment will comprise the subjects of inquiry in this course. We will investigate systems of spatial and physical organization as found in the landscape in various forms and structures from forest to farm and from tent to tenement as examples. The intersection of these systems found in accessible locals will be investigated in the field through on site drawings using simple media and sketchbooks. These studies will then form the basis for the iteration of more developed images depicting environments both existing and imagined. Some time will be spent on observing people and various life forms as they populate and interact within these spaces to various ends.

51-365 Creative Technology Sprints

Intermittent: 9 units

In this course, we will take computational approaches to explore information design in space. Students will consider the interactivity and readability of information when creating data-driven systems. They will learn Javascript programming and use P5.js for their interactive systems. There will be three projects: 1) Speech-responsive Kiosk; 2) Immersive Space using Projection; and 3) Data Visualization using Holo Lens. There is no prerequisite for this course, but basic understanding of typography and information design is expected.

51-367 Design Center: Computational Design Thinking

Intermittent: 9 units

In this course, we will explore creative coding in the context of communication and interaction design and use it as a primary medium to consider form, content and context for designing systems. Specifically, we will use computation as process and material for perceiving and generating forms through crafting the relationships between input and output. In other words, we will create artifacts computationally by designing formations through constructing algorithms and manipulating parameters for recognizing, deconstructing and generalizing patterns across solutions. There will be three group projects to explore the following concepts: 1) Rhythms and Patterns, 2) Structures and Relationships, and 3) Conditionals and Events. There is no prerequisite for this course, but strong understanding of typography, grid, and visual system is expected. In addition, since coding is an integral part of this course, it is assumed that you already have prior experience with programming or will spend time outside of class to learn and understand the basics on your own (links to online tutorial videos will be provided).

51-368 Moving Pictures

Intermittent: 9 units

The objective of this course is to provide students with a practical, technical and theoretical foundation in video work. Students leaving this class will have gained knowledge of developing a moving picture from start to finish. Students will learn how to storyboard/scamp, plan/scout, produce, and post-produce. Equally importantly students will develop their own visual esthetics through the creation of 4 short videos.

51-369 You Are Here: Identity & Place

Intermittent: 9 units

Placemaking is a practice that strengthens the connection between people and the public spaces they share. In this course we will explore the identity of spaces, the theories of how we navigate environments, and the ways that designers can define, craft, and/or express the identity of the places we go. This will take the form of projects that ask you to design and prototype permanent and temporary identity systems, custom typography, and full scale physical interventions.

51-371 Futures I

Fall: 4.5 units

The Futures I course focuses on aligning near term design action with longer time horizons aimed at sustainable futures. We introduce the students to Design Futures. Design is defined as "an experimental type of design that integrates Futures Thinking with Design Thinking." A distinguishing feature of design in our usage is the focus on aligning current action with long-term sustainability goals. The course covers different approaches to interpreting the future: from the extrapolations of trend forecasting, through the risk assessments of scenario planning, to attempts to steering the present through backcasting. Students explore the future through utopian and dystopian fictions that are created by authors, filmmakers and themselves. Students also attempt to evaluate futures in terms of their longer-term consequences.

51-372 Persuasion

Spring: 9 units

Examine written argumentation, oral presentations, artifact exhibitions, but also branding and social media. Students learn how to position their design ideas and connect them to the people and organizations that will increase their perceived value to target audiences. A focus of the course is on argument by precedent, where students build the significance of their innovations by situating them historically.

51-373 Futures II

Intermittent: 4.5 units

This course, paired with Futures I (51371), is the second half of a semester-long deep dive into foresight/futures for emerging designers. It represents a turn from learning basic concepts and methods in the futures field, toward more advanced, applied approaches at the cutting edge of strategy, co-design, worldbuilding, and transmedia storytelling.

51-374 Preparing for Design Practice

Intermittent: 4.5 units

This course helps design students formulate individual plans for their professional practice. In a ramp-up to Confluence, the first half of the class is devoted to developing and organizing portfolios, writing and designing resumes and cover letters and practicing interviewing skills. After Confluence, the second half is devoted to self-evaluation and reflection, guest lectures by early-career and later career designers and field trips that explore various aspects of a professional design career as well as other post-graduate opportunities. This course is geared towards Seniors and MA students, but Juniors applying for internships are also welcome.

51-375 Meaning in Images

Intermittent: 4.5 units

Images abound in our culture. This course takes a critical look at many different kinds of photographic images to understand how they operate in our culture to inform, persuade, and entertain various audiences. The content for this course will be generated from looking at, thinking about and discussing issues discovered while studying well-known to lesser-known images that range from photographs used in ad campaigns, to photographs that are used in scientific representation, to snapshots in family photo albums, to photographs that are used to show social injustices, to photographs that exist in museum collections. Readings will be assigned and short writing exercises will be required throughout the semester. In addition, photography assignments will be given. Design majors will have preference. Requirement: a digital camera. 15 students, junior and senior Design Majors.

51-376 Semantics & Aesthetics

Intermittent: 4.5 units

The course will explore the principles of visual composition, proportioning systems and the rules of order as it relates to art, architecture and design. The class will involve extensive reading and discussion of these topics in class. Some project work will also be required but minimal to the reading. A reading list will be provided. Instructor permission required for non-Design majors.

51-377 Design Center: Sensing Environments

Intermittent: 9 units

Whereas UX Design is typically described as shaping the immediate environment between a user and an object/interface, this course will instruct you in techniques, methods, and vocabularies to expand the scale of your design. Course content will give students experience integrating and shaping their current work into 2-3 other levels of scale, such as a single room, building, campus, and neighborhood. Students will walk away with an understanding of environments that will expand their range of capability, fitting for interdisciplinary application within fields such as social innovation, community development, public policy, architecture, and urban design.

51-378 Developing Form with Sketches & Models

Intermittent: 4.5 units

Development of Form with Models and amp; Sketches

51-379 Spatial Computing Design

Intermittent: 9 units

In this class, we will use Motion Tracking and Spatialized Outputs to design spatial computing experiences-collective, distributed, and localized interactions in a physical environment. We will work in a classroom instrumented with infrared cameras, digital projectors, and Sound Hologram technology (Wave Field Synthesis). In Unity 3D and using a digital twin of this classroom, we will program the interactions (in C#) to be tested in the physical space. Although some of these technologies relate to AR and VR systems, we will create experiences in the physical world without the interference of screens, headphones, and/or headset devices. This project-based class focuses on advancing research through prototyping and testing working implementations. The class sessions are structured around tutorials, short lectures, working sessions, and reviews.

51-380 Experiential Media Design

Intermittent: 9 units

Experiential Media Design focuses on the theory, methodology and history behind the design, development and interpretation of experiential media systems. The class incorporates a multidisciplinary approach to the study of complex media systems as technological, political, economic, socio-cultural and personal experiences. Topics covered include media and communications theory, cultural studies, qualitative and quantitative methodology, design principles, human-computer-interaction, information visualization and representation, user studies and evaluation. Students will create and critique a variety of integrated media systems demonstrating technical competence, aesthetic knowledge, analytic rigor and theoretical relevance. This class is open to Junior and amp; Senior Design Majors, and others by permission of the instructor.

51-382 Design Center: Design for Social Innovation

Spring: 9 units

Design for social innovation is a seminar that traces the history and application of design methods to solving social problems. The course will weave together themes from readings in design, business, public policy, technology, social service, international relations and current events. The course will review examples of successful and failed social innovations from local, regional, national and international contexts. Students will learn the role of governments, technology, funding, infrastructure, mindset, emotion, and cultural factors in addressing problems in the social sector. The course will include a real-world problem-solving component where students (in teams or individually) will write a paper, design an artifact or intervention, propose a project or conduct a short design research study that addresses a real-world problem that impacts a local community.

51-384 Design Center: Co-Designing for Social Innovation

Intermittent: 4.5 units

This course is for students considering how their work can contribute to a positive societal shift. Through a mix of lecture, readings, classroom activities and short field assignments, the course covers models of change, and methods, approaches, and skills that support the emergence of new social patterns. Such work necessarily involves diverse stakeholders, the complexity of human relationships and beliefs, and the challenges of power, conflict, exclusion and inequity. For that reason, this course helps students make first steps in preparing to facilitate creative change among diverse stakeholders attending to the conditions for generative dialogue, listening to all voices, and hosting the long process of co-creation.

51-385 Design for Service

Intermittent: 9 units

We all have an idea of what a good service is and #8212; when everything clicks into place, when you feel a little surprised and delighted because of the thoughtfulness and smoothness. And we know what it's like when a service goes wrong and #8212; missed flight connections leading to sleeping on an airport floor, sitting for too long in a doctor's waiting room, a website or app acting tone deaf in a sensitive situation. So what does it take to get a service right? And how can our services best communicate and reflect their interactions with us when they're integrating different streams of data? We will explore the fundamentals of service design in this lecture/studio class. In the first part of the class, we'll begin with a set of modules on tools and practices of service design. Then, you'll put them to use in a group project, in which you design and prototype a service. Our goals (and the objectives of this class) will be to learn service design fundamentals by hypothesizing, experimenting, building, testing our assumptions, sometimes failing, tweaking, and improving. Some great visitors will join us too, in person and virtually, to provide real-world insights about service design.

51-387 Introduction to DeXign Futures

Intermittent: 9 units

As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students learn the basic design skills necessary explore the forces that drive change in the future and learn to align innovation strategically with the trajectories of those forces.

51-390 Social Interaction Design in Community

Intermittent: 9 units

The course looks at Design for Social Innovation principles and practices, Documentary Photography, and Design Research while walking the streets, talking to residents, and working with organizations in a Pittsburgh neighborhood to understand its challenges. Students will examine Social Design case studies, with a focus on Problem Reframing processes (Dorst), and Solution Amplification (Manzini), and various design-enabled Theories of Change. They will also explore histories and theories of Documentary Photography. For the project/ethnographic portion of the class, students will work in teams of two within a neighborhood, and partner with residents and organizations. These collaborations will help students see the challenges of the community from an insiders point of view, in order for them to design appropriate responses to some of those challenges.

51-392 Images and Communication

Intermittent: 4.5 units

No one doubts the value of photography as a means of recording life. Even if we don't think of ourselves as photographers, digital cameras make it easy to photograph our families, our trips, and aspects of our life that we want to remember. But beyond snapshots, can photography also teach us how to see? And how do they teach us about the world? And, what are the qualities inherent in photographs that make them effective as artifacts of communication? Does looking through the camera's viewfinder sensitize us to world and help us see more? Or, as some writers suggest, does the camera interfere with experiencing the world fully. This course explores seeing with the camera and the many issues that arise when one snaps the shutter. We will be looking at a range of different kinds of photographic images, understanding their contexts, and how to read them. Designers and other visual people use photographs extensively in their work. This course endeavors to make students more aware of their decisions and actions when making photographs as well as how to judge a photograph's effectiveness. The issues that we discuss using photographs, relate to other kinds of visual images, as well. We will be making photographs as we are discussing critical issues in photography that come out of readings. Students must own a digital camera but no prior photographic experience is necessary.

51-393 Design Studies: Object-Based Histories at the Museum

Intermittent: 4.5 units

Object-Based Histories utilizes as its primary source Extraordinary Ordinary Things, the design collection installation of more than 300 works at Carnegie Museum of Art. In a small group setting students in this elective will consider historic and contemporary designs within the museum galleries. Through close looking and conversation, we will explore designers, makers, and users and their various cultural contexts. This course takes a its premise that if objects in the world are solutions, we can learn to intuit the questions. In so doing, we gain insights into human nature, cultures, and the built environment. Students will expand their knowledge of design histories, materials, and technologies and hone their skills in visual analysis, historical imagination, and critical thinking.

51-396 Design Center: Design for Zero Carbon Lifestyles

Intermittent: 4.5 units

In this mini-course, students focus on aspects of Sustainable Development Goals: #13 Climate Action, #12 Responsible Consumption and Production, #11 Sustainable Cities and Communities, #9 Industry, Innovation, and Infrastructure, and #7 Affordable and Clean Energy. Students explore how to become the agents of change around the challenges of the climate emergency focused on the design of zero-carbon lifestyles. Projects focus on zero-carbon lifestyles on two levels: individual and campus life. This course is open to all kinds of designers ranging from architecture, art, business, computer science, HCI, engineering, psychology and so forth.

51-399 Junior Independent Study

All Semesters

Guidelines for independent study in the Design office. Proposals must be approved by faculty before registration.

51-400 Transition Design

All Semesters: 9 units

Transition Design: Designing for Systems-Level Change. This course will provide an overview of the emerging field of Transition Design, which proposes societal transitions toward more sustainable futures. The idea of intentional (designed) societal transitions has become a global meme and involves an understanding of the complex dynamics of socio-technical-ecological systems which form the context for many of today's wicked problems (climate change, loss of biodiversity, pollution, growing gap between rich/poor, etc.). Through a mix of lecture, readings, classroom activities and projects, students will be introduced to the emerging Transition Design process which focuses on framing problems in large, spatio-temporal contexts, resolving conflict among stakeholder groups and facilitating the co-creation, and transition towards, desirable, long-term futures. This course will prepare students for work in transdisciplinary teams to address large, societal problems that require a deep understanding of the anatomy and dynamics of complex systems.

Course Website: <https://transitiondesignseminarcmu.net/>

51-418 Diversity, Equity, Inclusion and Design

Intermittent: 9 units

In this course, students will explore Diversity, Equity, and Inclusion (DEI) issues as they relate to the School of Design to propose and possibly implement and initiate efforts to begin to address some of these issues. We will learn about the systems, structures, and tools for, by, and with Design at the intersection of DEI. Foundational lectures, discussions, and hands-on workshops combined with a review and consolidation of precedent research and work supporting the definition and scope of DEI. Through a variety of group exercises, directed working sessions, guest lectures by subject matter experts, readings, case studies, and more, students will be guided through an intensive learning process. Students will work individually and collaboratively, including working with the full course cohort. We will ask questions such as: What do we mean by DEI? What are the opportunities and challenges within the design discipline and its pipelines? Within design pedagogy and practice? With designers and designing? What happens if we put DEI at the center of our work? How do we develop new postures and mindsets that place DEI at the forefront of the School of Design at Carnegie Mellon University?

51-419 Design Center: Design's Reverberations: Ripple Effects of Innovative Ideas

Intermittent: 4.5 units

When an idea is implemented to effect change, what happens to its context? This course provides students from different backgrounds with the opportunity to think through multiple dimensions of and orientations to the notion of solving a problem through making and theorizing. Through the lens of design-driven processes, the class will delve deeper into the conditions in which problems are solved and place focused attention on domino and ripple effects of effecting change. Students will uncover what may be brewing underneath the surface of a given context, such as the residual impact of historic events, changes to the topographical landscape of a neighborhood, connections between individual behavior change to the growth of niche cultures, sensorial shifts in the environment due to climate change, emerging instabilities in a system sparked by the implementation of an idea, amongst others. Students will use present-day contexts, such as neighborhoods or particular initiatives, as points of departure to answer the questions when an idea is implemented to effect change, what happens to its context? Students in this course will gain a deeper understanding of the complexities of instigating change to inform their ethos and practice.

51-420 Sensing Place through Color

Intermittent: 9 units

The world is enhanced by color in every facet of our environment, but we often overlook unimaginable color interactions. The application of color depends mainly upon a trial and error process of selection, comparison, interaction, and evaluation. This course is about learning to look at the world with color filters and exploring ways to utilize color in new and meaningful ways. Through a series of prompts, journaling exercises, and personal experiences, we will reimagine our sense of place through color.

51-421 Design Center: Data Visualization

Intermittent: 9 units

This is a comprehensive data visualization primer. In Data Visualization course students will learn how to parse and visualize data. Starting with multiple introductory exercises on the foundations of data viz, we will then investigate tools, principles and best practice by which computational design driven data visualizations are operating today. Then, students will decide on a data set of their choice (necessary complexity given), to either create a data visualization with an emphasis on telling a story, or to generate a meaningful data art piece with an emphasis on engagement and experience. Project outcomes can be expressed through a variety of forms of the students choosing, from print posters, websites to mind-bending interactive experiences. These will be documented and presented on the final crit. This course assumes that students are already familiar with elementary programming (in any language), such as for() loops, if() statements, arrays[] and functions(). Participants will use Javascript and very likely popular creative coding toolkits like p5.js, Basil.js, Snap.svg, GSAP, D3.js etc. for their projects.

Course Website: <http://bit.ly/CMUDataViz> (<http://bit.ly/CMUDataViz/>)**51-423 Pieces 2.0: Social Innovation: Desis Lab**

Intermittent: 9 units

In this class, students will identify a social problem and take a holistic design approach to solving it. They will design a product/product line—anything from a set of tools to help older adults lead a more active lifestyle, to re-envisioned collateral for the Lupus Foundation Pennsylvania. After or in tandem with the creation of this product, the student will construct an image, which will entail print media, a Web presence, packaging, and photography. By creating the product and its "marketing" effort from top-to-bottom, the student will gain a diverse set of skills in design as well as a richer understanding of the product. In the end, all the pieces will come together to create a well-refined image.

51-424 Web Portfolio

Intermittent: 4.5 units

This course will provide an opportunity for students to design and code their online portfolio. The course covers basic elements of Web design along with the foundations of HTML, CSS, Javascript and Flash as components of the design process. Prior experience with HTML is encouraged but tutorials will be provided if necessary. This is not an Actionscript programming course.

51-425 Design Center: Beginning Book Arts Lab

Fall and Spring: 6 units

This is a class of basic issues regarding hand bookbinding and letterpress printing. Its purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-426 Design Center: Beginning Book Arts Lab

Spring: 6 units

Beginning Book Arts Lab Class. 6units. (This class is a prerequisite for the Advanced Book Arts Workshop Lab Class). This is a class of basic issues regarding hand bookbinding and letterpress printing. Its purpose is to develop a basic structural sense of book forms, of flat format work and of three dimensional forms. Learning hand craft techniques, developing hand skills and the sensitivity to materials are also a goal. Binding projects assigned will target the unique nature of papers, fabrics and archival card-boards. Structural procedures and techniques will be identified with each assigned binding project. The binding projects will be: A hardcover for a paper back book, a single signature book, a multi-signature book with flat spine, and a box construction. The box project is designed and crafted to contain a small letterpress printed class edition, either in book form, or as a set of un-bound pages. The letterpress component teaches the standard issues, unique to the relief process, in press work, handset procedure of cast metal type, page form spacing, lock-up of pages in press, proofing, and production printing. Each semester a small class edition project of text content and image, in two-color registration, is designed, hand set and printed. Image generation can be by hand cut block, assembled type-high forms, or digital process to polymer plate. This class is not to be repeated.

51-427 Advanced Book Arts Workshop

Intermittent: 9 units

Students will be required to plan and design projects that relate to binding, or digital printing, or letterpress printing, or hand-setting of cast metal type. Projects utilizing a combination of all processes can be planned as well. Experimental work, or Artists' Books are also encouraged. In this class structure students will be able to plan and design projects that are complete books, with printed content, or with out content. Other flat structures, and three dimensional containers are examples of general forms that will be categorized as binding work. Students who wish to enroll in this course must have already taken Beginning Book Arts, and must also speak to the instructor directly about project ideas. Emphasis for binding is working independently with a greater level of hand craft and a sensitivity to materials. Emphasis for letterpress printing is to learn in depth, and master, the general mechanical process for doing press work. Emphasis for hand typesetting is on gaining an understanding of the system of cast metal type, and to develop a sensitivity to typographic principles. Instruction will be given on an individual basis through consultation at strategic times throughout the semester. Project evaluation will be based on the success of the project work compared to each student's written project proposal at the start of the semester. The Advanced Workshop in Book Arts can be repeated. For more complex project work this class can be continued for the following semester.

51-428 Time, Motion and Communication

Intermittent: 9 units

This course focuses on designing and presenting time-based messages on screen. The differences between paper-based and screen-based communication are discussed and become departure points for projects. Working with word, image, sound, and motion and #8212; in Adobe AfterEffects and #8212; students develop responses to a variety of project briefs. Brief histories of animation, experimental films, and title sequences, as well as experimental music provide conceptual models to our discussions. An attitude of exploration is stressed, with an emphasis on visual voice, performance, and communication. Content will include personal messages and timely information. Proficiency with AfterEffects is a firm requirement. Preference will be given to junior and senior Design students.

51-434 Experimental Form

Intermittent: 9 units

The Experimental Form Studio looks broadly at the discipline of industrial design with an emphasis on creating new paradigms for interactive objects. This course encourages an exploratory study of physical objects and artifacts and provides a creative and intellectual forum to re-imagine our relationship with objects. Each independently-themed project presents opportunities to consider embedded mechanics and technology, objects as interactive media, and experience-driven design. Experimental Form, at its most basic, is a process that blends play and inquiry in an open-ended way finding the unexpected through tinkering and trying something you don't quite know how to do, guided by imagination, curiosity, and a disciplinary skillset. In this sense, Experimental Form complements the core Product Design Studio sequence by providing a playground for intellectual discourse, experimental trial and error, and refining individual processes for designing. Prerequisites: 51-343 or 51-311 or 51-248

51-437 Design Center: The Emerging Ecological Worldview

Intermittent: 9 units

In this seminar it will be argued that the mechanistic worldview which has permeated Western (and Westernized) thinking and society since the scientific revolution has been crumbling for several decades: its place is gradually being taken by an emerging ecological (or holistic) worldview. This worldview coheres themes such as relationality, interdependence, self-organization, diversity, pluralism, creativity, context, process and wholeness. These themes have in many ways been embodied in the evolution of natural systems/organisms, ecosystems and the earth itself and have enormous implications for how we inhabit the places in which we live and the planet as a whole, if we and the 'More-Than-Human World' are to flourish. We will ask what it means to 'think ecologically' and what are the implications of the ecological worldview for how systems of all kinds (technological, infrastructural, political, social, economic) are designed. Students will explore how the application of ecological principles can help us to more authentically 'inhabit' and satisfy our needs in the places in which we live, and inform strategies for designing for futures that are more sustainable, equitable and desirable

Course Website: https://docs.google.com/document/d/1l_j7yptD8-MWkSaI9SZZdRKSqmscedSHsSH3TLbSVjs/edit?usp=sharing (https://docs.google.com/document/d/1l_j7yptD8-MWkSaI9SZZdRKSqmscedSHsSH3TLbSVjs/edit?usp=sharing)

51-441 Foundation of BME Design

Fall: 6 units

This course focuses on the Product Development scope and framing of a new medical device. Students will work together in an interdisciplinary team with Biomedical Engineering students to identify medical professional or patient needs through behavioral research and participatory research methods. This course deliverable requires the team to propose the problem space and develop a design brief and plan for the following Spring semester to implement. Prerequisite: Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-442 BME Design Project

Spring: 9 units

This course is the second in sequence of prototyping and testing a proposed medical device product. The course consists of modules for the development of a project plan, background research, hazard analysis, setting product specifications based on user requirements, detailed design and analysis, prototype development and final documentation and presentation. All products developed will respond to the needs of appropriate market segments; resulting products will be deemed safe, effective, useful, usable and desirable by those segments. Students will produce a form model, functional prototype, marketing plan, and manufacturing plan of their product. Prerequisite: 51-441 (3 units, Fall) Foundations of Biomedical Engineering Design (or permission of the instructor). Junior level design or higher with studio training. Solid modeling or surface modeling recommended.

51-451 Fundamentals of Joinery & Furniture Design

Fall: 9 units

Intensive introduction to traditional joinery techniques and the properties of wood through the use of textbook studies and lab experiments. Emphasis placed on how these techniques and properties influence design decisions. Students will learn how to set up, sharpen and use traditional hand powered tools. This acquired knowledge will be applied in the design and realization of a piece of wooden furniture. Limited enrollment. Lab fee and material purchases required. Prerequisite: 51-350

51-452 Furniture Design II

Spring: 9 units

A continuation of 51-451, this course explores a much broader range of issues related to furniture design. Students will identify and define in a proposal the area of furniture design they intend to investigate and then produce one or more furniture pieces developed from their findings. Materials and processes applied to the project are limited only by the resources the student can bring to bear. Assigned readings and a series of in-class discussions will focus on the influence of workmanship in design, and on how the behavior of the user is influenced by the form or esthetic language of the artifact. Lab fee and amp; material purchases required. Prerequisite: 51-451

51-455 DeXign the Future: Human Centered Innovation for Exponential Times

Intermittent: 9 units

DEXIGN THE FUTURE: Human Centered Innovation for Exponential Times As corporations, governmental organizations, and civil associations face accelerating change in uncertain times, increasingly they are looking to designers for new ways of thinking and acting. Designers today are engaged as thought leaders, strategists, activists, and agents of change in complex socio-technical problems throughout private, public, civil and philanthropic sectors worldwide. For designers trained to shape futures defined by uncertainty and change, these exponential times represent unprecedented creative opportunities for innovation. In this course, students explore methods and tools for design in exponential times to shape uncertain futures. Students will explore the forces that drive change in the future (i.e., social, economic, political, environmental, technological), and learn to align innovation strategically with the trajectories of those forces. The design project that drives everything else is the future of mega-metropolitan regions, the hubs of innovation where 70% of people in the world and 75% of Americans will live in 2050. In the semester long project, students create scenarios for Life 2050 in Metro 3.0, using Pittsburgh as a locus and focusing on a project within urban systems such as Sustainable Production and amp; Consumption, Lifelong Learning, Human Development and Resilient Community.

51-471 Design Center: Imaginaries Lab: Research through Design

Fall: 9 units

The Imaginaries Lab is a research studio developing design methods to explore and support people's imagining both new ways to understand, and new ways to live, in an increasingly complex world. This course, running over three weekends, immerses you in a creative 'research through design' project, including prototyping and using experimental design methods 'in the wild', and in depth. You will learn and develop a variety of tools for conducting innovative forms of research through design, including exploring how people think, understand and imagine complex social and technological concepts, and envision futures, and depending on your expertise or interest, will be able to concentrate on applying particular skills as part of multidisciplinary teams. For example, a project might include speculative design, ethnographic inquiry, physical computing, and novel creative methods. We will aim to turn your work into a published output for a conference or journal, so there is additionally the opportunity to gain experience in this aspect of academic research.

Course Website: <http://imaginari.es>**51-478 Speculative Critical Design**

Intermittent: 9 units

This praxis-based course will actively engage futures research through the integration of findings from critical readings, ethnographic research, mediated storytelling and hybrid prototyping. Using techniques of inversion, defamiliarization, uncertainty scenarios, everyday practice and good old-fashioned humor, we will create objects, systems and experiences that stimulate conversation, debate and understanding. The course seeks to produce a diversity of 'what will?' and 'what if?' cultural provocations that deeply examine possible, unwanted and seductive futures. This course is open to Junior and Senior Design majors, or by permission of the instructor.

51-480 Design Capstone Project: Service Design & Social Innovation

Spring: 12 units

Learn how to work independently, applying skills/knowledge in Products, Communications, Environments to the research/definition/development/testing of a project that focuses on the design of a service or social innovation that warrants investigation; deepen understanding of service and amp; social innovation design principles and how they are put into practice. Prerequisite: 51-481

51-481 Senior Design Studio

Fall: 12 units

As contributors to the built world, the School of Design recognizes that designers can significantly impact society and embrace the responsibility to propose new ways of seeing and exploring the numerous dimensions of any given problem space. This studio is the next stage of that preparation. Structured into three separate discipline sections communications, products, and environments each will continue to leverage and evolve its disciplinary practices, ways of working, and purview to develop positive and impactful design proposals.

Prerequisites: 51-330 or 51-360 or 51-350

51-483 Debating the Roles & Responsibilities of the Designer

Intermittent: 9 units

Designers are expected to play a role in creating aspirational lifestyles through products and services, and informing and influencing human behavior on small and large scales. However what impact does or should the designer have on our lives, our society, and culture? Through readings, discussions, and team activity, students will construct pro and con arguments and debate the role and responsibility of the designer in a critical and fun way.

51-485 Design Center: Imaginaries Lab: New Ways to Think

Intermittent: 4.5 units

In this course, we'll carry out 'research through design' projects using experimental investigative methods in the wild, focusing on new ways to think and understand in an increasingly complex world. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-487 Design Center: Imaginaries Lab: New Ways To Live, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: <http://imaginari.es/newways> (<http://imaginari.es/newways/>)**51-486 Designing Experiences for Learning**

Intermittent: 9 units

This course focuses on designing experiences that engage people in educational activities that enhance their learning through meaningful, memorable, and enjoyable interactions with information. Throughout the course, students investigate the intersection of design thinking, UI/UX design, cognitive studies, social sciences, instructional design, and educational pedagogy as a way of developing knowledge and skills in designing experiences for learners. Students study topics that are often difficult to grasp and collaboratively build a taxonomy of content types based on common and differentiating characteristics to identify design opportunities. Through readings, projects, and class exercises, students explore how people perceive and process information, what motivates them to learn, and what constitutes an experience. The course introduces students to traditional and emergent learning tools and methods as a means of defining affordances and limitations of various learning approaches and mediums. It also provides students the opportunity to apply what they learn through the design, testing, and assessment of learning experiences that they create.

51-487 Design Center: Imaginaries Lab: New Ways to Live

Intermittent: 4.5 units

Focusing on new ways to live and experience the world, now and in the future, we'll do practical investigative 'research through design' projects using experimental methods in the wild. Learn and develop a variety of tools for conducting innovative forms of research through design, focused on exploring how people think, understand and imagine complex social and technological concepts, and envision futures. By the end of the course students will have worked on an interdisciplinary research project, including with an external partner, drawing on a number of disciplinary domains, and have experience with different kinds of design research and practice, from speculative and critical design to participatory design, as well as developing the skills and experience necessary to innovate with, and deploy, those methods. This course is a complement to 51-485 Design Center: Imaginaries Lab: New Ways To Think, but is independent of it, and eitheror bothcourses can be taken without overlap (we will be doing different projects, with a different focus).

Course Website: <http://imaginari.es/newways> (<http://imaginari.es/newways/>)**51-489 Design Center: Designing Narratives Across Media**

Intermittent: 4.5 units

This studio mini will deal with designing at the intersection of three things: developing rich worlds, i.e. experiences and narratives, understanding how different mediums work and what they do, and understanding how genres work in terms of conventions around content and form. Students will thus be exposed to thought from various disciplines like media, genre, literary and cultural theory in order to create rich, interactive worlds as part of a single design studio project. Specifically, we will be analyzing and reflecting on the phenomenon of interactivity by studying how mediums like interactive print, film and cinema, tangible board/tabletop games, and installation art can be employed using the frame of "Other" futurisms (sinofuturism, afrofuturism, indofuturism etc.) that are part of the general practice of speculative and science fiction throughout the world. We will engage with popular and fringe cultural texts and artifacts, so students should be prepared to spend time watching movies, playing games, reading books etc. in an analytic, reflexive manner in order to better understand the different strategies that authors have developed in order to evoke specific responses in their audiences. In this class, you will bring the technical skills required - the object will be to collaborate with others with complementary skill-sets in order to create one lavish, intricate transmedial project that will draw people into the depth of its world. This is not an art class - we will discuss the designerly applications of this type of work, particularly with reference to design studies, speculative/critical design, ontological design, and decolonial design. The object of the course will be to make "other" ways of designing in the world visible and experiment with the boundaries of design as a practice of cultural production.

51-493 Design Center: Decoloniality: Past, Present & Future

All Semesters: 4.5 units

The relevance of decoloniality in design. The role of media and technology in shaping and advancing particular ways of understanding the world The future of decoloniality: where do we go from here?

51-494 Design that Lasts

Intermittent: 6 units

Never have we wanted, owned, and wasted so much "stuff." Our consumptive path through modern life leaves a wake of social and ecological destruction and #8212; sneakers worn only once, forgotten smartphones languishing in drawers, and abandoned IoT devices promising solutions to problems that don't exist. By what perverse alchemy do our newest, coolest things so readily transform into meaningless junk? This design elective investigates why we throw away things that still work, and shows how we can design products and services that last. This is a studio class, with a substantial theoretical thread woven through it. We will therefore spend about half our time on lectures, readings, and debates, and the other half on studio practice, project coaching tutorials, and group critique. The result, a seven-week journey toward an "experience heavy, material light" design sensibility. A vital and timely new design philosophy that reveals how meaning emerges from designed encounters between people and things, explores ways to increase the quality and longevity of our relationships with objects, and the systems behind them, and ultimately, demonstrates why design can and #8212; and must and #8212; lead the transition to a sustainable future.

51-495 History and Future of Interaction Design

Intermittent: 9 units

The history of Interaction Design is far richer than what is commonly known among students and teachers, practicing designers and entrepreneurs. Understanding IxD's origins and evolution helps us realize the promises and possibly avoid some of the pitfalls of IxD's future. This course blends readings, lectures, discussions, and prototyping as a means for students to experience this history as if first-hand. Students become immersed in pragmatic yet mind-expanding examples of person-machine interactions and #8212; such as MEMEX, Musicolour, Hypertext, Dynabook, Fun Palace, Colloquy of Mobiles, Architecture Machine, THOUGHTSTICKER, Architrainer, and Hypercard. Through period articles and subsequent perspectives, students research a handful of historical innovations and then prototype key concepts from that history, forefronting what has been lost in modern commercial implementations. This offers students a hands-on experience of the history of IxD. To explore IxDs future, students are invited to invent it and #8212; to prototype their individual future vision of interactive experiences. The course is especially suitable for students with interest or background in interaction design, computational design, responsive architecture, and interactive media.

51-496 Systems, Cybernetics, Conversation

Intermittent: 9 units

Across many design disciplines architecture and computational design, media and interaction design, design of services and organizations methods for grappling with complex adaptive systems is now table stakes. Furthermore, design today demands profound, authentic attention to equity, human and non-human living systems, climate and environment, sustainability and ethics. Overall, designers must have skills to collaborate in cross-disciplinary teams. An encompassing framework for these disparate disciplines and domains of 21st-century design is the transdisciplinarity (or "antidisciplinarity") of Cybernetics. Cybernetics can be understood as the study of "systems with purpose", whether machines or living things, including their unpredictable interactions. Central to Cybernetics is conversation as a mechanism of design, inclusivity, participation, innovation, and the impetus to action. The course offers systems frameworks and models of conversation that are also relevant to Designing for the Internet of Things (48-675), Inquiry into Computation Design (48-727), and Design Studies: Systems (51-277). Class time balances readings, discussion panels, and guest conversations with executing assignments that involve systems modeling; creating conditions for designing that are participatory and inclusive; and prototyping in a range of media (installations, screen-based interactivity, physical prototypes, workshops, etc.) that offer responses to global wicked challenges.

51-498 Design Center: What If?

Intermittent: 6 units

WHAT IF? is a media, arts, and design-led exploration of speculation, conjecture, and storytelling. Using play and worldbuilding, we will investigate science fictional constructs, conjure alternative pasts and presents, voyage to the edge of the imaginable, and blur the borders between possible and impossible. How do you build a time machine, anyway?

51-499 Senior Independent Study

All Semesters

Proposal forms are available on the Design Intranet. Proposals must be approved by faculty before pre-registration.

51-818 Diversity, Equity, Inclusion and Design

Intermittent: 12 units

In this course, students will explore Diversity, Equity, and Inclusion (DEI) issues as they relate to the School of Design to propose and possibly implement and initiate efforts to begin to address some of these issues. We will learn about the systems, structures, and tools for, by, and with Design at the intersection of DEI. Foundational lectures, discussions, and hands-on workshops combined with a review and consolidation of precedent research and work supporting the definition and scope of DEI. Through a variety of group exercises, directed working sessions, guest lectures by subject matter experts, readings, case studies, and more, students will be guided through an intensive learning process. Students will work individually and collaboratively, including working with the full course cohort. We will ask questions such as: What do we mean by DEI? What are the opportunities and challenges within the design discipline and its pipelines? Within design pedagogy and practice? With designers and designing? What happens if we put DEI at the center of our work? How do we develop new postures and mindsets that place DEI at the forefront of the School of Design at Carnegie Mellon University?

School of Drama

Location: Purnell Center for the Arts, 221
www.drama.cmu.edu (<http://www.drama.cmu.edu>)

The School of Drama at Carnegie Mellon University is the oldest drama program in the country. CMU Drama offers rigorous, world-class classical training in theater while providing thorough preparation for contemporary media.

As a member of the Consortium of Conservatory Theater Training Programs, the school chooses students to participate in the program based on their potential ability. Every Drama student is treated as a member of a theatrical organization and must acquire experience in all phases of the dramatic arts. Students are also asked to broaden their knowledge through courses in the other colleges of the university. The undergraduate Drama program, which incorporates approximately 200 students, leads to a Bachelor of Fine Arts in Drama. The options available are: Acting, Music Theater, Design, Production Technology and Management, Directing, and Dramaturgy. The production of plays, a natural extension of demanding class work, is our lab, and constitutes one of the school's major activities. The choice of texts used is determined by the particular needs of current students. Each semester, 15 to 25 lab productions, directed by faculty, guest directors, and advanced students, are presented in our three theater spaces. The labs range from completely mounted, full-length dramatic and musical works to more simply produced directing projects and one-acts. The Drama program is rigorous and exacting, making demands on students that necessitate good health, a willingness to work and a commitment to professional discipline at all times. Because of full daytime class work and heavy production schedules, much production preparation takes place in the evening. Drama students, therefore, are advised to live in residence halls or in the immediate vicinity of the campus.

The information contained in this section is accurate as of July 2023 and is subject to change. Please contact the School of Drama at drama-relations@andrew.cmu.edu with any questions.

Options in Drama

Acting and Musical Theater Option

The Acting and Musical Theater option is designed to prepare the student for immediate entry into the profession. It is a sequence-based training program with accumulative skills building upon each other over the course of four years. It is a conservatory training course, and the curriculum focuses primarily on the technique and craft of theater. At the same time it offers skills that are applicable to all media. Courses in acting, voice, speech, movement, and theater history are integral parts of the program at all four levels. In addition to studio classes, Acting majors are required to take a number of electives outside the school of drama to expand their intellectual curiosity and worldview. All students must demonstrate a commitment to growth, show continued progress in their work and in the knowledge of their craft, and show a respect for professional standards in discipline, quality and ethics. The freshman year is a discovery year and provides an introduction to basic skills—working from self, learning to play objectives and actions and the beginning of character exploration. In the sophomore year these skills are solidified and deepened as more sophisticated, verbally complex material is introduced, through a focus on in-depth scene study, both contemporary and Shakespeare. In the junior year students continue to develop their craft by investigating a variety of styles. Skills are now tested and strengthened through public performance. The senior year provides a bridge from training to the professional world and offers the opportunity to appear on the School of Drama's main stage. At the end of the senior year, students are introduced to the profession through Showcase performances in New York City and Los Angeles. The students in the Music Theater program share the training philosophy and much of the same curriculum as the acting option. In addition, they take courses particular to the demands of Music Theater. These include private voice along with training in a variety of dance techniques (Ballet, Jazz, Tap, Dunham Technique and Broadway Styles) and music theater styles and skills.

Directing Option

The John Wells Directing Program promotes creativity, intellectual curiosity, critical thinking, a broad and well-rounded understanding of the theater and leadership ability. It provides a detailed exploration of the technique of directing for stage and for camera. The curriculum is designed

for those serious about the art of directing and intending to pursue a career in theater, film or television.

Course work in scenic design, lighting, media, and costume design develops the students' visual sophistication as well as an understanding of how these elements combine in practical production situations to create new worlds. Stage management skills are studied and practiced. Theater history, criticism, playwriting, new play development and theater management classes introduce the student to the wide range of knowledge necessary for directing. Participation in acting classes develop a deep understanding of the actor's journey as well as the communication skills necessary for collaboration. There are many avenues open for practical application: scene work in class, a short film written and directed by students, studio projects and even participating in choreography events. The broad scope of the directing curriculum encourages the director's interaction with all the theatrical disciplines. Collaboration in all forms, so necessary to the art, is the goal.

Production Technology and Management (PTM) Option

The Production Technology and Management Option develops the technologists and managers of the future with an intensive curriculum designed to synthesize academic development and production experience. The curriculum focuses on the production requirements of live performance, in the form of traditional theatrical presentation, while also providing exposure to television, film and emerging technology-based art forms. Integrated in a world-class research university environment, the School of Drama is uniquely positioned to contribute to the advancement of the collaborative arts. The goal of the three PTM programs is to prepare today's students to become tomorrow's leading professionals in the entertainment industry.

All undergraduate students begin with the development of visual and written communication skills. The first three semesters immerse the student in a range of collaborative and individual studies: scenery, costume, sound and lighting design fundamentals; dramatic structure and interpretation; manual and computer-based drafting; perspective and figure drawing, fundamentals of directing; production management and preparation, history of art and history of architecture and décor. The last five semesters focus the student's skills within their chosen area of concentration: Technical Direction, Stage & Production Management, or Production Technology..

Technical Direction students are offered classes in: material applications, metal working techniques, structural design, scenic crafts, fabrication design and detailing, machinery design, rigging techniques, electronic design fundamentals, automation system technology, technical management and production management. Technical Directors may take a single semester internship at an approved regional or commercial producing organization in lieu of one semester of study. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Technical Direction program of study.

Stage and Production Management students are offered classes in: an extensive study of stage management and production management, theater management, leadership, problem solving and business communications, in addition to classes in resource management in all technical areas. Production assignments supplement classroom learning and development throughout the program. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Stage & Production Management program of study.

Production Technology students are offered a variety of classes in: scenic fabrication and technology, lighting technology, audio technology, show networking, technical, production, theater and stage management and design courses within one or more design discipline. Production responsibilities for Production Technology students may include roles as Lighting Managers, Technicians and Programmers, Audio Engineers, Mixers and Technicians, Video Engineers and Technicians, Scenic Automation Technicians and Managers and Network Integrators. Student-selected elective courses outside the School of Drama provide balance and breadth to the professional undergraduate education offered in the Production Technology program of study.

Dramaturgy Option

The dramaturgy curriculum provides students with a strong background in theatrical practice, dramatic literature, and humanities. A core course of study focusing on building the skills for production dramaturgy is augmented by an English minor along with directed electives in history, foreign languages, and other non-drama courses to build a firm foundation in both theater and the liberal arts.

Students in the dramaturgy option also cultivate their intellectual prowess, analytical skills, and artistic passions through integral involvement in the School of Drama's productions. Dramaturgy students work with directors, playwrights, designers, managers, and actors in the conception and execution of productions, bringing their knowledge of theater history and dramatic structure, their skills in script analysis and contextual research, and their capacity to engage in collaborative conversation into the rehearsal room. These skills also serve dramaturgy students as they practice the art of audience engagement.

The Dramaturgy Option specializes in new play development, production support, critical writing, audience engagement, season planning, and artistic leadership. The wide ranging curriculum makes it an excellent program of study for students interested in theater history and theory, playwriting, and cultural studies. Alumni from the dramaturgy program have built careers not only in theater but also in film and television as well as in arts management, in literary and casting agencies, and in education.

Theater Studies Option

The Theater Studies option offers students from any of the School's conservatory areas of specialized study the opportunity to continue developing their theater related skills while expanding their interests to other artistic and academic areas. This option will only be available to Drama students who have completed their sophomore year in the School of Drama (ie: two years of conservatory training). Students are required to write a proposal outlining their interests in the Theater Studies option, and the proposal must be approved by the Head of the School of Drama.

The goal of the Theater Studies option is to enable students to explore the diverse opportunities for which conservatory drama training can be a basis, and to examine the possibility of post graduate education in a new area of specialization after obtaining a BFA in Drama. As the intent of the Theater Studies option is to broaden your experiences, a semester studying abroad or participating in a recommended internship is required for one semester, either in the fall or spring. Individualized courses of study are established for each student in consultation with an appropriate faculty advisor.

Curriculum

The School of Drama curriculum is continuously reviewed and modified in an effort to provide the best conservatory experience for undergraduate students in the School of Drama. The following curriculum is subject to change. Not all requirements are listed, and units are often variable within each Option based on performances, production assignments, and individual projects.

Acting Option

First Year

| Fall | | Units |
|--------|---|-----------|
| 54-101 | Acting I | 10 |
| 54-011 | Introduction to Alexander Technique | 1 |
| 54-103 | Speech I | 4 |
| 54-105 | Voice for the Stage I | 5 |
| 54-107 | Movement I | 4 |
| 54-110 | Text for Actors (mini 2, section A) | 2 |
| 54-175 | Conservatory Hour (mini 1) | 1 |
| 54-177 | Foundations of Drama I (section A) | 6 |
| 99-101 | Computing @ Carnegie Mellon (usually taken over the summer) | 3 |
| 54-362 | Anti-Racist & Equitable Practices in Theater | 6 |
| 76-101 | Interpretation and Argument | 9 |
| | | 51 |
| Spring | | Units |
| 54-102 | Acting I | 10 |

| | | |
|--------|-------------------------------|------------------|
| 54-104 | Speech I | 6 |
| 54-106 | Voice for the Stage I | 5 |
| 54-108 | Movement I | 4 |
| 54-159 | Production Practicum | 6 |
| xx-xxx | Global Perspectives | 9 |
| xx-xxx | Non-Drama elective | 6-9 |
| 54-285 | Alexander Technique Tutorials | 1.5 |
| | | 47.5-50.5 |

Sophomore Year

| Fall | | Units |
|--------|------------------------------------|------------------|
| 54-201 | Acting II | 12 |
| 54-203 | Voice and Speech II | 4 |
| 54-207 | Movement II | 4 |
| 54-211 | Actor Dance II | 3 |
| 54-281 | Foundations of Drama II * | 6 |
| 54-213 | Singing for Actors II (Optional) | 3 |
| 62-314 | The Art of Personal Finance | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-209 | Voice and Speech II: Practicums | 3 |
| 54-285 | Alexander Technique Tutorials | 1.5 |
| xx-xxx | Global Perspectives (if not taken) | |
| | | 48.5-51.5 |

| Spring | | Units |
|-----------|--|------------------|
| 54-202 | Acting II | 12 |
| 54-204 | Voice and Speech II | 4 |
| 54-208 | Movement II | 3 |
| 54-212 | Actor Dance II | 3 |
| 54-242 | Improvisation | 2 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-214 | Singing for Actors II (Optional) | 3 |
| 54-159 | Production Practicum | 6 |
| 54-285 | Alexander Technique Tutorials (optional) | 1.5 |
| 54-209 | Voice and Speech II: Practicums (2 minis) | 3 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| or 54-336 | Musical Theater History | |
| | | 49.5-52.5 |

Junior Year

| Fall | | Units |
|--------|---|------------------|
| 54-301 | Acting III (JPP + mini-2) | 10 |
| 54-305 | Voice for the Stage III | 5 |
| 54-307 | Movement III | 5 |
| 54-309 | Dialects and Accents | 4 |
| 54-325 | Actor Dance III | 2 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-317 | Singing for Actors III (Optional) | 2 |
| 54-327 | Auditioning for TV/Film (Optional) | 2 |
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-311 | Rehearsal and Performance III (if assigned) | 16 |
| | | 53.5-56.5 |
| Spring | | Units |
| 54-302 | Acting III (mini-3 & mini-4) | 10 |
| 54-310 | Dialects and Accents | 6 |
| 54-306 | Voice for the Stage III | 5 |
| 54-308 | Movement III | 5 |
| 54-312 | Rehearsal and Performance III | 16 |

| | | |
|--------|--|-----|
| 54-326 | Actor Dance III | 2 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-318 | Singing for Actors III (Optional) | 2 |
| 54-335 | Auditioning for the Stage (optional) | 2 |
| 54-285 | Alexander Technique Tutorials (optional) | 1.5 |

55.5-58.5

Senior Year

| Fall | | Units |
|--------|--|-------|
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-407 | Movement IV | 6 |
| 54-413 | Showcase (mini 2) | 6 |
| 54-493 | Business of Acting & The Practice & 54-229 The Biz - In Practice | 4 |
| 54-411 | Rehearsal and Performance IV | 16 |
| 54-519 | Acting for the Camera | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-403 | Advanced Speech Techniques (mini 1) | 3 |

48.5-51.5

| Spring | | Units |
|--------|--|-------|
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-412 | Rehearsal and Performance IV | 16 |
| 54-414 | Showcase | 9 |
| 54-520 | Acting for the Camera | 7 |
| 54-438 | Acting IV-Improv (mini 4) | 3 |
| xx-xxx | Non-Drama Elective | 6-9 |

42.5-45.5

NON-DRAMA ELECTIVES:

Actors take a minimum of four Non-Drama Electives, 6-9 units each.

Music Theater Option

First Year

| Fall | | Units |
|--------|---|-------|
| 54-101 | Acting I | 10 |
| 54-103 | Speech I | 4 |
| 54-105 | Voice for the Stage I | 5 |
| 54-107 | Movement I | 4 |
| 54-110 | Text for Actors (mini-2, section B) | 2 |
| 54-123 | Dance Technique I: Physical Mechanics and Anatomy | 5 |
| 54-125 | Music Skills I | 4 |
| 54-175 | Conservatory Hour (mini 1) | 1 |
| 54-500 | Voice Lab | 5 |
| 99-101 | Computing @ Carnegie Mellon (usually taken over the summer) | 3 |
| 54-362 | Anti-Racist & Equitable Practices in Theater | 6 |
| 54-011 | Introduction to Alexander Technique (mini-1) | 1 |

50

| Spring | | Units |
|--------|-----------------------------------|-------|
| 54-102 | Acting I | 10 |
| 54-104 | Speech I | 6 |
| 54-106 | Voice for the Stage I | 5 |
| 54-108 | Movement I | 4 |
| 54-124 | Dance I: Applying Dance Technique | 5 |
| 54-126 | Music Skills II | 4 |

| | | |
|--------|-----------------------------|---|
| 54-159 | Production Practicum | 6 |
| 54-500 | Voice Lab | 5 |
| 54-177 | Foundations of Drama I | 6 |
| 76-101 | Interpretation and Argument | 9 |

60

Sophomore Year

| Fall | | Units |
|--------|--|-------|
| 54-201 | Acting II | 12 |
| 54-203 | Voice and Speech II | 4 |
| 54-205 | Dance II: Pillars to Build Dance Technique | 3 |
| 54-207 | Movement II | 4 |
| 54-217 | Jazz II | 2 |
| 54-219 | Special Topics: Music Theater History and Repertoire | 6 |
| 54-223 | Tap II - Rhythmic Technique/Foundational to Complex | 2 |
| 54-500 | Voice Lab | 5 |
| 54-209 | Voice and Speech II: Practicums | 3 |
| 54-285 | Alexander Technique Tutorials (optional) | 1.5 |
| 62-314 | The Art of Personal Finance (mini)** | 6 |
| xx-xxx | Global Perspectives | 9 |

57.5

| Spring | | Units |
|--------|--|-------|
| 54-202 | Acting II | 12 |
| 54-204 | Voice and Speech II | 4 |
| 54-206 | Dance II: Pillars to Build Dance Technique | 3 |
| 54-208 | Movement II | 3 |
| 54-218 | Jazz II | 2 |
| 54-224 | Tap II: Rhythmic Technique/Foundational to Complex | 2 |
| 54-220 | Acting A Song | 4 |
| 54-159 | Production Practicum | 6 |
| 54-281 | Foundations of Drama II | 6 |
| 54-500 | Voice Lab | 5 |
| 54-209 | Voice and Speech II: Practicums | 3 |
| 54-285 | Alexander Technique Tutorials (optional) | 1.5 |

51.5

Junior Year

| Fall | | Units |
|--------|---|-------|
| 54-301 | Acting III (JPP & mini-2) | 10 |
| 54-305 | Voice for the Stage III | 5 |
| 54-309 | Dialects and Accents | 4 |
| 54-313 | Dance III: Expand the Dynamics of Dance Technique | 3 |
| 54-315 | Jazz III | 2 |
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-319 | Cabaret | 6 |
| 54-323 | Tap III - Expand Percussive Rhythms | 2 |
| 54-500 | Voice Lab | 5 |
| 54-311 | Rehearsal and Performance III (or in spring) | 16 |
| 54-327 | Auditioning for TV/Film (optional) | 2 |

56.5

| Spring | | Units |
|--------|--|-------|
| 54-302 | Acting III (mini-3 & mini-4) | 10 |
| 54-306 | Voice for the Stage III | 5 |
| 54-310 | Dialects and Accents | 6 |
| 54-312 | Rehearsal and Performance III | 16 |
| 54-314 | Dance III: Expand Dynamic of Dance Technique | 3 |

| | | |
|--------|--|-----|
| 54-316 | Jazz III | 2 |
| 54-324 | Tap III: Expand Percussive Rhythms | 2 |
| 54-500 | Voice Lab | 5 |
| 54-374 | Musical Theater Audition | 5 |
| 54-335 | Auditioning for the Stage (optional) | 2 |
| 54-285 | Alexander Technique Tutorials (optional) | 1.5 |

57.5

Senior Year

| Fall | Units | |
|--------|--|-----|
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-413 | Showcase (mini 2) | 6 |
| 54-418 | Songs for Showcase (mini 2) | 2 |
| 54-403 | Advanced Speech Techniques (mini 1) | 3 |
| 54-415 | Broadway Dance Styles | 5 |
| 54-493 | Business of Acting & The Practice & 54-229 In-practice | 4 |
| 54-500 | Voice Lab | 5 |
| 54-519 | Acting for the Camera | 6 |
| 54-411 | Rehearsal and Performance IV | 16 |

48.5

| Spring | Units | |
|--------|--|-----|
| 54-285 | Alexander Technique Tutorials (Optional) | 1.5 |
| 54-412 | Rehearsal and Performance IV | 16 |
| 54-438 | Acting IV-Improv (mini 4) | 3 |
| 54-414 | Showcase | 9 |
| 54-416 | Broadway Styles | 5 |
| 54-500 | Voice Lab /Senior Coaching | 5 |
| 54-520 | Acting for the Camera | 7 |
| 54-418 | Songs for Showcase | 2 |

48.5

** Music Theater students are required to take an approved Scientific and Quantitative Reasoning elective. Students usually take 62-314 The Art of Personal Finance to fulfill this requirement.

Design Option

First Year

| Fall | Units | |
|------------------|---|----|
| 54-151 | Stagecraft (combination of minis) | 13 |
| 54-157 | Production Science | 6 |
| 54-169 | Studiocraft 1 | 13 |
| 54-171 | Basic Design 1 | 6 |
| 54-175 | Conservatory Hour | 1 |
| 99-101 | Computing @ Carnegie Mellon (taken over summer) | 3 |
| 54-362 or 54-177 | Anti-Racist & Equitable Practices in Theater Foundations of Drama I | 6 |
| 76-101 | Interpretation and Argument | 9 |

57

| Spring | Units | |
|------------------|---|----|
| 54-152 | Stagecraft (combination of minis) | 13 |
| 54-158 | Production Planning | 6 |
| 54-170 | Studiocraft 2 | 8 |
| 54-172 | Basic Design 2 | 6 |
| 54-177 or 54-362 | Foundations of Drama I Anti-Racist & Equitable Practices in Theater | 6 |

| | | |
|--------|-------------------------------|-----|
| xx-xxx | Non-Drama Elective (optional) | 6-9 |
| xx-xxx | Global Perspectives | 9 |

54-57

Sophomore Year

| Fall - ALL DESIGN | Units | |
|-------------------|--|-----|
| 54-281 | Foundations of Drama II (section B/or in the spring) * | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-284 | Fundamentals of Directing | 6 |
| 54-231 | Design for the Stage | 6 |
| 54-232 | Design for the Stage: Lighting | 4 |
| 54-249 | Stagecraft II | 14 |
| 54-271 | Technical Management | 6 |

48-51

| Spring - ALL DESIGN | Units | |
|--|--|--------|
| 54-xxx | Production Preparation | varies |
| 54-281 | Foundations of Drama II (if not in fall) | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| Spring - SOUND DESIGN (consult with advisor) | | Units |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-666 | Production Audio | 6 |
| 54-117 | Design Collaboration Project (mini) | 3 |
| 54-548 | Sound Forum | 1 |

| Spring - COSTUME DESIGN (consult with advisor) | Units | |
|--|---|-------|
| 54-162 | Introduction to Costume Design | 6 |
| 54-230 | Make-Up for Designers | 6 |
| 54-346 | Introduction to Costume Construction | 6 |
| 54-447 | Figure Drawing (or in a future semester) | 3 |
| 54-117 | Design Collaboration Project (mini) | 3 |
| Spring - SCENIC DESIGN (consult with advisor) | | Units |
| 54-250 | Introduction to Scenic Design | 6 |
| 54-386 | Scenic Design Skills: 3D Model Making (mini) | 4 |
| 54-392 | Scenic Design Skills: 2D Drawing and Rendering (mini) | 4 |
| 54-350 | Scenic Design Forum | 1 |
| 54-117 | Design Collaboration Project | 3 |

| Spring - LIGHTING DESIGN (consult with advisor) | Units | |
|---|--|---|
| 54-252 | Introduction to Lighting Design | 6 |
| 54-368 | Introduction to Lighting Management | 6 |
| 54-287 | Introduction to Lighting Design Skills | 3 |
| 54-117 | Design Collaboration Project (mini) | 3 |
| 54-337 | Introduction to Lighting Technology | 6 |
| 54-384 | Lighting Design Forum | 1 |

| Spring - VIDEO & MEDIA DESIGN (consult with advisor) | Units | |
|--|--|------|
| 60-110 | Foundations: Time-Based Media (This is not a non-Drama elective) | 10 |
| 54-297 | VMD Systems Studio | 6 |
| 54-XXX | Other Design "Co-Option" course (optional, likely the Collaboration Project) | Var. |
| XX-XXX | VMD Interdepartmental Course | 9 |

Junior Year

| Fall - ALL DESIGN | Units | |
|--|--|--------|
| 54-xxx | Production Preparation | varies |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |
| Fall - SOUND DESIGN (consult with advisor) | | Units |
| 54-267 | Conceptual Sound Design | 9 |

| | | |
|--|---|--------|
| 54-389 | Composition for Theatrical Sound Design 1 | 9 |
| 54-505 | Ear Training | 1 |
| 54-548 | Sound Forum | 1 |
| Fall - COSTUME DESIGN (consult with advisor) | | Units |
| 54-245 | Who Wore What: When, Where, and Why | 6 |
| 54-341 | Fundamentals of Costume Design | 9 |
| 54-373 | Draping Fundamentals | 3 |
| 54-486 | Understanding Textiles (mini-2) | 3 |
| 54-511 | Millinery I (every other year) | 9 |
| 54-539 | Fabric Dyeing I (optional, every other year) | 9 |
| 54-473 | Drawing for Theatrical Designers | 9 |
| 54-441 | Costume Design for Dance (mini) | 5 |
| Fall - SCENIC DESIGN (consult with advisor) | | Units |
| 54-237 | Scenic Painting I | 6 |
| 54-239 | History of Architecture and Decor 1: Ancients to Gothic | 6 |
| 54-331 | Scenic Design: Explorations | 9 |
| 54-383 | Introduction to Digital Media | 9 |
| 54-350 | Scenic Design Forum | 1 |
| Fall - LIGHTING DESIGN (consult with advisor) | | Units |
| 54-524 | Dance Lighting Design 2 (mini-2) | 3 |
| 54-351 | Theatrical Lighting Design | 9 |
| 54-367 | Lighting Design Skills (mini-1) | 3 |
| 54-469 | Dance Lighting Design 1 (mini-1) | 3 |
| 54-525 | Entertainment Lighting Programming | 9 |
| 54-396 | Theatrical Lighting Management | 6 |
| 54-384 | Lighting Design Forum | 1 |
| Fall - VIDEO & MEDIA DESIGN (consult with advisor) | | Units |
| 54-399 | Decoding Media | 9 |
| xx-xxx | VMD Interdepartmental Course | 9 |
| 54-498 | Expanded Theater (if offered) | 6 |
| 54-xxx | Other Design "Co-option" course (optional) | varies |
| 54-476 | Media Creation Studio | 6 |
| Spring - ALL DESIGN | | Units |
| 54-xxx | Production Preparation | varies |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| Spring - SOUND DESIGN (consult with advisor) | | Units |
| 54-390 | Composition for Theatrical Sound Design 2 | 9 |
| 54-505 | Ear Training | 1 |
| 54-328 | Advanced Digital Sound Design Skills | 6 |
| 54-548 | Sound Forum | 1 |
| Spring - COSTUME DESIGN (consult with advisor) | | Units |
| 54-442 | Costume Design for the Classics | 5 |
| 54-467 | Costume Design with Music | 5 |
| 54-450 | Painting for the Theatrical Designer (every other year) or | 9 |
| or 54-470 | Costume Rendering | |
| 54-xxx | Costume Crafts Mini (optional) | 6 |
| 54-xxx | Fabric Painting (every other year, optional) | 9 |
| 54-444 | Advanced Designer Draping (optional) mini-4 | 6 |
| 54-246 | Who Wore What: When, Where, Why II | 6 |
| 54-379 | Captured Storytelling (optional) | 7 |
| Spring - SCENIC DESIGN (consult with advisor) | | Units |
| 54-238 | Scenic Painting II | 6 |
| 54-240 | History of Architecture and Decor 2: Renaissance to the 21st Century | 6 |
| 54-332 | Scenic Design: Boot Camp (mini-3 & mini-4) | 4.5 |
| 54-450 | Painting for the Theatrical Designer (or approved substitute) | 4.5 |
| 54-350 | Scenic Design Forum | 1 |
| 54-344 | Concept Character Illustration (or approved sub) | 4.5 |
| Spring - LIGHTING DESIGN (consult with advisor) | | Units |
| 54-352 | Musical and Opera Lighting Design | 9 |
| 54-565 | Dance/Light (mini-3) | 3 |
| 54-384 | Lighting Design Forum | 1 |
| Spring - VIDEO & MEDIA DESIGN (consult with advisor) | | Units |
| 54-400 | Staging Media | 9 |
| xx-xxx | VMD Approved Interdepartmental class | 9 |
| 54-xxx | Other Design "Co-Option" course (optional) | 6 |
| Senior Year | | |
| Fall - ALL DESIGN | | Units |
| 54-xxx | Production Preparation | varies |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |
| Fall - SOUND DESIGN (consult with advisor) | | Units |
| 54-268 | Collaborations in Organized Sound | 3 |
| 54-505 | Ear Training | 1 |
| 54-398 | Special Topics in Sound Design | 9 |
| Fall - COSTUME DESIGN (consult with advisor) | | Units |
| 54-447 | Figure Drawing | 3 |
| 54-511 | Millinery I (offered every other year) or 54-539 Fabric Dyeing (if offered, optional) | 9 |
| 54-xxx | Costume Crafts Mini (varies each semester, optional) | |
| 54-239 | History of Architecture and Decor 1: Ancients to Gothic | 6 |
| 54-498 | Expanded Theater | 9 |
| 54-450 | Painting for the Theatrical Designer (if offered) | 9 |
| Fall - SCENIC DESIGN (consult with advisor) | | Units |
| 54-473 | Drawing for Theatrical Designers or approved drawing sub | 9 |
| 54-350 | Scenic Design Forum | 1 |
| 54-498 | Expanded Theater | 9 |
| Fall - LIGHTING DESIGN (consult with advisor) | | Units |
| 54-524 | Dance Lighting Design 2 (mini-2) (may be repeated) | 3 |
| 54-491 | Concert Lighting Design | 9 |
| 54-525 | Entertainment Lighting Programming (Optional) | 9 |
| 54-384 | Lighting Design Forum | 1 |
| Fall - VIDEO & MEDIA DESIGN (consult with advisor) | | Units |
| 54-xxx | Other Design "Co-Option" course | varies |
| 54-521 | Video Media Design Senior Thesis (or approved Advanced VMD course) | Var. |
| 54-461 | Experimental Capture | 12 |
| Spring - ALL DESIGN | | Units |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-361 | Production Preparation | Var. |
| Spring - SOUND DESIGN (consult with advisor) | | Units |
| 54-372 | Theatre for the Ear | 6 |
| 54-397 | Sound Design For Interactive Environments | 9 |

| | | |
|--|---|-----------|
| 54-505 | Ear Training | 1 |
| 54-548 | Sound Forum | 1 |
| Spring - COSTUME DESIGN (consult with advisor) | | Units |
| 54-450 | Painting for the Theatrical Designer (every other year) or | 9 |
| or 54-470 | Costume Rendering | |
| 54-xxx | Costume Crafts Mini (varies each semester) | |
| 54-xxx | Transforming Inspiration (optional) | 9 |
| 54-xxx | Costume Design for TV & Film (optional) | |
| 54-240 | History of Architecture and Decor 2: Renaissance to the 21st Century | 6 |
| 54-379 | Captured Storytelling (optional) | 7 |
| 54-446 | Professional Prep for Costume Designers | 3 |
| Spring - SCENIC DESIGN (consult with advisor) | | Units |
| 54-432 | Scenic Design: Design for Spaces (mini-3 & mini-4) | 4.5 & 4.5 |
| 54-450 | Painting for the Theatrical Designer (or approved sub in Arch or Art 9 units) | 9 |
| 54-350 | Scenic Design Forum | 1 |
| Spring - LIGHTING DESIGN (consult with advisor) | | Units |
| 54-452 | Architectural Lighting Design | 9 |
| 54-565 | Dance/Light (may be repeated) | 3 |
| 54-384 | Lighting Design Forum | 1 |
| Spring - VIDEO & MEDIA DESIGN (consult with advisor) | | Units |
| 54-xxx | Other Design "Co-Option" course (optional) | Var. |
| 54-521 | Video Media Design Senior Thesis (or Advanced VMD course) | Var. |

NON-DRAMA ELECTIVES:

Designers take a minimum of five Non-Drama Electives, 6-9 units each.

Notes:

** All Designers are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

Directing Option

First Year

| | | |
|--------|---|-----------|
| Fall | | Units |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-167 | Acting for Directors I | 10 |
| 54-107 | Movement I (section C) | 4 |
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-110 | Text for Actors (mini-2, section C) | 2 |
| 54-175 | Conservatory Hour (mini 1) | 1 |
| 99-101 | Computing @ Carnegie Mellon (usually taken over the summer) | 3 |
| 54-517 | Directors Common Hour | 1 |
| 54-159 | Production Practicum | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (section A) | 6 |
| | | 51 |

| | | |
|--------|---|-------|
| Spring | | Units |
| 54-122 | Directing I: A Director's Preparation | 9 |
| 54-168 | Acting for Directors I | 10 |
| 54-159 | Production Practicum | 6 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-177 | Foundations of Drama I | 6 |
| 76-101 | Interpretation and Argument or (76106 & 76108) | 9 |

| | | |
|--------|-----------------------|-----------|
| 54-517 | Directors Common Hour | 1 |
| | | 50 |

Sophomore Year

| | | |
|--------|--|-----------|
| Fall | | Units |
| 54-233 | Acting For Directors II | 12 |
| 54-221 | Directing II: In the Studio | 9 |
| 54-281 | Foundations of Drama II (or in the spring) | 6 |
| 54-517 | Directors Common Hour | 1 |
| 54-271 | Technical Management (Optional) | 6 |
| 62-314 | The Art of Personal Finance (mini) | 6 |
| 76-270 | Writing for the Professions (section E) | 9 |
| 54-xxx | Directing: Production II (by assignment) | |
| | | 49 |
| Spring | | Units |
| 54-234 | Acting For Directors II | 12 |
| 54-222 | Directing II: In The Room | 9 |
| 54-330 | Introduction to Stage Management | 6 |
| 54-117 | Design Collaboration Project (mini) | 3 |
| 54-517 | Directors Common Hour | 1 |
| xx-xxx | Non-Drama Elective (Global Perspective if not completed) | 9 |
| 54-xxx | Directing: Production II (by assignment) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (or in a future semester) | 6 |
| | | 52 |

Junior Year

| | | |
|--------|--|-----------|
| Fall | | Units |
| 54-322 | Directing III: INTRODUCTION TO TV & FILM DIRECTING | 9 |
| 54-517 | Directors Common Hour | 1 |
| 54-271 | Technical Management (Optional) | 6 |
| 54-391 | Lighting Design for Directors | 4 |
| 85-102 | Introduction to Psychology (section F or one that fits) | 9 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism or 54-336 (if needed) | 6 |
| | | 35 |

Spring - NYC TEPPER INTERNSHIP SEMESTER
Tepper Semester courses (register with Syracuse)

36

Senior Year

| | | |
|--------|--|--------------|
| Fall | | Units |
| 54-457 | Directing: Production IV (Capstone prep) | 6/16 |
| 54-517 | Directors Common Hour | 1 |
| 54-422 | Directing IV: Next Steps | 9 |
| 54-247 | Dramaturgy 6: In Company | 9 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-498 | Expanded Theater | 9 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |
| | | 40-49 |
| Spring | | Units |
| 54-422 | Directing IV: Next Steps | 9 |
| 54-458 | Directing: Production IV (Capstone) | Var. |
| xx-xxx | Non-Drama Elective | 6-9 |

| | | |
|--------|---|---|
| 54-517 | Directors Common Hour | 1 |
| 54-379 | Captured Storytelling (if offered) | 7 |
| 54-433 | The Basics of Self-Producing for Theater Artists | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) | 6 |

35-39**NON-DRAMA ELECTIVES:**

Directors take a minimum of four Non-Drama Electives, 6-9 units each.

Notes:

** One semester of Directing Production IV: Senior Thesis Play is required. Second semester is optional.

Production Technology and Management (PTM) Option

First Year

| Fall | | Units |
|-----------|--|-------|
| 54-151 | Stagecraft | 13 |
| 54-157 | Production Science | 6 |
| 54-169 | Studiocraft 1 | 13 |
| 54-171 | Basic Design 1 | 6 |
| 54-175 | Conservatory Hour | 1 |
| 99-101 | Computing @ Carnegie Mellon (usually taken over the summer) | 3 |
| 54-362 | Anti-Racist & Equitable Practices in Theater | 6 |
| or 54-177 | Foundations of Drama I | |
| 76-101 | Interpretation and Argument | 9 |

57

| Spring | | Units |
|-----------|--|-------|
| 54-152 | Stagecraft | 13 |
| 54-170 | Studiocraft 2 | 8 |
| 54-158 | Production Planning | 6 |
| 54-172 | Basic Design 2 | 6 |
| 54-176 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| or 54-362 | Anti-Racist & Equitable Practices in Theater | |
| xx-xxx | Global Perspectives | 9 |

49**Sophomore Year**

| Fall | | Units |
|--------|--|-------|
| 54-231 | Design for the Stage | 6 |
| 54-232 | Design for the Stage: Lighting | 4 |
| 54-271 | Technical Management | 6 |
| 54-249 | Stagecraft II | 14 |
| 54-281 | Foundations of Drama II (section B) (or in spring) ** | 6 |
| 54-284 | Fundamentals of Directing | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |

48-51

| Spring - ALL PTM | | Units |
|----------------------------------|---|--------|
| 54-xxx | Production Preparation (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) | varies |
| 54-272 | Scenic Fabrication and Installation | 6 |
| 54-334 | Production Resource Management | 6 |
| 54-281 | Foundations of Drama II (if not in fall) | 6 |
| xx-xxx | Non-Drama Elective | 6 |
| Spring - PTM TECHNICAL DIRECTION | | Units |
| 54-264 | Welding | 4 |
| 54-265 | Advanced Fabrication 1 | 6 |
| 54-330 | Introduction to Stage Management | 6 |

| | | |
|--|----------------------------------|---|
| Spring - PTM STAGE & PRODUCTION MANAGEMENT (SPM) | Units | |
| 54-666 | Production Audio | 6 |
| 54-330 | Introduction to Stage Management | 6 |

Junior Year

| Fall - ALL PTM | | Units |
|----------------|---|--------|
| 54-xxx | Production Preparation (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) | varies |
| 54-273 | Technical Direction I | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |

| Fall - PTM TECHNICAL DIRECTION | | Units |
|--------------------------------|----------------------------|-------|
| 54-353 | Structural Design I ~ | 9 |
| or 54-366 | Physics of Stage Machinery | |
| 54-295 | Advanced Fabrication 2 | 6 |

| Fall - PTM SPM | | Units |
|----------------|------------------------------|-------|
| 54-266 | Stage Management: Cue Lab | 4 |
| 54-339 | Stage Management Seminar | 3 |
| 54-380 | Music Reading for Production | 3 |
| 54-455 | Production Data Manipulation | 9 |

| Spring - ALL PTM | | Units |
|------------------|---|-------|
| 54-381 | Special Topics in Drama: History, Literature and Criticism *** (if needed) | 6 |
| 54-xxx | Production Prep (64 units total for PT over 5 semesters 8, 12, 12, 16, 16) | |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-355 | 30 Hour OSHA (if offered) | 2 |

| Spring - PTM TECHNICAL DIRECTION | | Units |
|----------------------------------|------------------------|-------|
| 54-354 | Structural Design II ~ | 9 |
| or 54-365 | Machine Design I | |
| 54-378 | Technical Direction II | 6 |

| Spring - PTM SPM | | Units |
|------------------|-------------------------------------|-------|
| 54-339 | Stage Management Seminar | 3 |
| 54-453 | Production Management Workshop | 3 |
| 54-368 | Introduction to Lighting Management | 6 |
| 54-454 | Advanced SM: Management Styles | 6 |
| 54-270 | Adv Topics in SM: Communication | 6 |

Senior Year

| Fall - ALL PTM | | Units |
|----------------|---|--------|
| 54-xxx | Production Preparation (64 units for PT over 5 semesters 8, 12, 12, 16, 16) | varies |
| 54-381 | Special Topics in Drama: History, Literature and Criticism *** (if needed) | 6 |
| xx-xxx | Non-Drama Elective | 6-9 |
| 54-333 | Production Personnel Management or 54-455 PDM (if needed) | 6 |

| Fall - PTM TECHNICAL DIRECTION | | Units |
|--------------------------------|-------------------------------------|-------|
| 54-477 | Technical Direction III | 6 |
| 54-353 | Structural Design I ~ | 9 |
| or 54-366 | Physics of Stage Machinery | |
| 54-376 | Entertainment Rigging | 3 |
| 54-279 | Embedded Electronics (if needed) | 3 |

| Fall - PTM SPM | | Units |
|----------------|--------------------------------|-------|
| 54-339 | Stage Management Seminar | 3 |
| 54-453 | Production Management Workshop | 3 |
| 54-454 | Advanced SM: Management Styles | 3 |

| Spring - ALL PTM | | Units |
|------------------|---|--------|
| 54-xxx | Production Preparation (64 units total for PT over 5 semesters) | varies |

| | | |
|----------------------------------|--|-------|
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) *** | 6 |
| 54-355 | 30 Hour OSHA (if not taken) | 2 |
| 54-468 | Theater Management (if not taken) | 6 |
| Spring - PTM TECHNICAL DIRECTION | | Units |
| 54-354 | Structural Design II | 9 |
| or 54-365 | Machine Design I | |
| 54-376 | Entertainment Rigging (optional) | 3 |
| 54-480 | Technical Direction IV | 6 |
| Spring - PTM SPM | | Units |
| 54-339 | Stage Management Seminar | 3 |
| 54-453 | Production Management Workshop | 3 |
| 54-475 | Advanced Topics in SM: Cross-Cultural & Interdisciplinary Collaboration | 6 |

NON-DRAMA ELECTIVES:

PTM students take a minimum of five Non-Drama Electives, 6-9 units each.

SMPM Students must complete 4 Directed Drama Electives.

Notes:

** Foundations of Drama II will be taken only one semester in the sophomore year. Sophomore PTM students will be required to take an approved Humanities and Social Sciences (H&SS) elective in the Deitrich College during the semester they are not taking Foundations of Drama II. This course counts as one of the required seven Non-Drama Electives.

*** All PTM students are required to complete Special Topics in Drama: History, Literature and Criticism. It may be taken at any time after Foundations II has been completed.

~ Classes offered in alternating years.

Production Technology (area within PTM)

| Fall | | Units |
|--------|---|-----------|
| 54-151 | Stagecraft | 13 |
| 54-157 | Production Science | 6 |
| 54-169 | Studiocraft 1 | 13 |
| 54-171 | Basic Design 1 | 6 |
| 54-175 | Conservatory Hour | 1 |
| 99-101 | Computing @ Carnegie Mellon (usually taken over the summer) | 3 |
| 54-362 | Anti-Racist & Equitable Practices in Theater or 54-177 Foundations of Drama I | 6 |
| 76-101 | Interpretation and Argument | 9 |
| | | 57 |

| Spring | | Units |
|--------|---|-----------|
| 54-152 | Stagecraft | 13 |
| 54-170 | Studiocraft 2 | 8 |
| 54-158 | Production Planning | 6 |
| 54-172 | Basic Design 2 | 6 |
| 54-177 | Foundations of Drama I or 54-362 Anti-Racist and Equitable Practices in Theater | 6 |
| xx-xxx | Global Perspectives | 9 |
| | | 48 |

| Fall | | Units |
|--------|--------------------------------|-------|
| 54-231 | Design for the Stage | 6 |
| 54-232 | Design for the Stage: Lighting | 4 |
| 54-271 | Technical Management | 6 |
| 54-249 | Stagecraft II | 14 |
| 54-281 | Foundations of Drama II ** | 6 |
| 54-284 | Fundamentals of Directing | 6 |

| xx-xxx | Non-Drama Elective | 6-9 |
|--------|--------------------|--------------|
| | | 48-51 |

| | | |
|---|---|-------|
| Production Technology-discuss timeline with advisor | | Units |
| 54-xxx | Production Preparation (5 semesters: 8, 12, 12, 16, 16 units) | 64 |
| 54-272 | Scenic Fabrication and Installation | 6 |
| 54-273 | Technical Direction I | 6 |
| 54-330 | Introduction to Stage Management | 6 |
| 54-334 | Production Resource Management | 6 |
| 54-333 | Production Personnel Management | 6 |
| 54-355 | 30 Hour OSHA | 2 |
| 54-464 | PTM Professional Practice | 3 |
| 54-468 | Theater Management | 6 |
| 54-359 | Introduction to Show Networking | 3 |
| 54-xxx | Show Networking Workshop | 3 |
| 54-368 | Introduction to Lighting Management (and 54-369) | 6 |
| or 54-666 | Production Audio | |
| 54-252 | Introduction to Lighting Design and 54-287 | 6 |
| or 54-166 | Introduction to Sound Design for Theatre | |
| or 54-297 | VMD Systems Studio | |

| | | |
|--------|--------------------|--|
| xx-xxx | Directed Electives | |
| xx-xxx | Directed Electives | |
| xx-xxx | Directed Electives | |

5 courses from the following: 54-509, 54-525, 54-527, 54-417,54-265, 54-295, 54-349, 54-353, 54-508

Dramaturgy Option

First Year

| Fall | | Units |
|--------|-----------------------------------|--------------|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-175 | Conservatory Hour (mini 1) | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-200 | Dramaturgy Forum | 1 |
| 76-101 | Interpretation and Argument | 9 |
| 82-xxx | Foreign Language * | 9-12 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 54-159 | Production Practicum (Run Crew) | 6 |
| | | 53-56 |

| Spring | | Units |
|--------|---|--------------|
| 54-159 | Production Practicum (Run Crew) | 6 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 82-xxx | Foreign Language * | 9-12 |
| 54-281 | Foundations of Drama II | 6 |
| 54-117 | Design Collaboration Project (mini-4) | 3 |
| 54-122 | Directing I: A Director's Preparation | 9 |
| 54-200 | Dramaturgy Forum | 1 |
| 54-362 | Anti-Racist & Equitable Practices in Theater | 6 |
| xx-xxx | Non-Dramaturgy Elective | |
| | | 49-52 |

Sophomore Year

| Fall | | Units |
|--------|--|--------|
| 54-256 | Dramaturgy 3: New Play Dramaturgy | 9 |
| 54-299 | Dramaturgy Production:Assistant (or in spring) | 9 |
| 54-200 | Dramaturgy Forum | 1 |
| 54-xxx | Production Preparation (by assignment) | varies |
| 54-219 | Special Topics: Music Theater History and Repertoire | 6 |
| xx-xxx | Playwriting or approved sub | |

| | | |
|--------|--|------|
| 82-xxx | Modern Language, if needed * | 9-12 |
| 54-239 | History of Architecture and Decor 1: Ancients to Gothic (or 54-240 in the spring) | 6 |
| 54-245 | Who Wore What: When, Where, and Why | 6 |
| 76-275 | Introduction to Critical Writing (or in Jr fall) | 9 |
| xx-xxx | Non-Dramaturgy Elective | |

55-58

| | | |
|--------|---|-------|
| Spring | | Units |
| xx-xxx | Playwriting or approved sub (if not in fall) | |
| 54-363 | Dramaturgy 4: Devising (in even years) | 9 |
| 54-xxx | Dramaturgy Production: Assistant (if not in fall) | 3 |
| 54-240 | History of Architecture and Decor 2: Renaissance to the 21st Century (if not 54-239 in fall) | 6 |
| 54-200 | Dramaturgy Forum | 1 |
| xx-xxx | Directed Elective | 9 |
| xx-xxx | Directed Elective | |
| xx-xxx | Non-Dramaturgy Elective | 6-9 |
| 82-xxx | Foreign Language, if needed * | 9-12 |

43-49

Junior Year

| | | |
|--------|--|-------|
| Fall | | Units |
| 54-200 | Dramaturgy Forum | 1 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-xxx | Dramaturgy: Production (or in spring) | 9/12 |
| xx-xxx | Directed Elective | 9 |
| 54-239 | History of Arch & Decor or 54-245 | 6 |
| 54-241 | Dramaturgy 5: Dramaturgy in Translation | 9 |
| xx-xxx | Directed Elective | |
| xx-xxx | Non-Dramaturgy Elective | |
| 54-485 | Embodied Rough Drafts (2 minis) | var |

31-40

| | | |
|--------|---|-------|
| Spring | | Units |
| 54-200 | Dramaturgy Forum | 1 |
| xx-xxx | Directed Elective | 9 |
| xx-xxx | Directed Elective | 9 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| xx-xxx | Non-Dramaturgy Elective | 6-9 |
| 54-363 | Dramaturgy 4: Devising (if needed) | 9 |
| 54-433 | The Basics of Self-Producing for Theater Artists (or approved sub) | 6 |
| 54-xxx | Dramaturgy: Production (if not in fall) | 9/12 |
| 54-485 | Embodied Rough Drafts (1 mini, if needed) | |

46-58

Senior Year

| | | |
|--------|--|-------|
| Fall | | Units |
| 54-200 | Dramaturgy Forum | 1 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| xx-xxx | Directed Elective | 9 |
| xx-xxx | Non-Dramaturgy Elective | 6-9 |
| 54-247 | Dramaturgy 6: In Company | 9 |
| 54-xxx | Dramaturgy Research Hours | 3 |
| 54-xxx | Dramaturgy: Production or Capstone Project | 9/12 |

34-46

| | | |
|--------|-------------------------------------|-------|
| Spring | | Units |
| 54-254 | New Play Development (if needed) | 9 |
| 54-200 | Dramaturgy Forum | 1 |
| 54-xxx | Dramaturgy 7: EXPO | |

| | | |
|--------|---|-----|
| 54-381 | Special Topics in Drama: History, Literature and Criticism (if needed) *** | 6 |
| xx-xxx | Directed Elective | 9 |
| 54-587 | Dramaturgy Production (if not in fall) | 12 |
| xx-xxx | Non-Dramaturgy Elective | 6-9 |
| 54-433 | The Basics of Self-Producing for Theater Artists (or approved sub) | 6 |

49-52

All Students must complete a minor in Literature and Cultural Studies in the English Department.

DIRECTED ELECTIVES: EUROPEAN STUDIES & HISTORY Units
Dramaturgy students take one European Studies course (cannot be an English course, but can be a History course) 9

Dramaturgy students take at least 3 History courses (two 200-level and one 300-level). One course must focus on history pre-1900, and one must focus on African, Asian, Latin American, or Caribbean studies. 27

DIRECTED ELECTIVES: FOREIGN LANGUAGE Units
Dramaturgy students take at least one Foreign Language course at the 200-level or above. 12

NON-DRAMATURGY ELECTIVES:

Dramaturgy students take a minimum of seven Non-Dramaturgy Electives, 6-9 units each.

Notes:

- * Dramaturgy students starting a modern language at the 100-level should begin in the fall of freshman year.
- *** Dramaturgy students are required to take a total of 12 units of Special Topics in Drama: History, Literature and Criticism during their junior and senior year.
- ~ Dramaturgy Internship may be completed in the summer, fall, or spring semester of junior or senior year.

Faculty

WENDY ARONS, Professor, Dramatic Literature - Ph.D., University of California, San Diego; Carnegie Mellon, 2007-

NATALIE BAKER-SHIRER, Associate Professor Emerita, Voice & Speech - M.F.A., University of Pittsburgh; Carnegie Mellon, 1992-

CLAUDIA BENACK, Associate Teaching Professor, Music Theatre - M.F.A., Carnegie Mellon; Carnegie Mellon, 1993-

STEWART BLACKWOOD, Assistant Professor, Composition and Sound Design - M.F.A., Sound Design, UC San Diego; Carnegie Mellon, 2023-

DICK BLOCK, Teaching Professor, Design - M.F.A., Northwestern University; Carnegie Mellon, 1988-

DAVID BOEVERS, Associate Professor, Production Technology and Management - M.F.A., Yale University; Carnegie Mellon, 2000-

C. TODD BROWN, Associate Teaching Professor, Lighting - B.A., Ohio State University; Carnegie Mellon, 2001-

JAMES CATON, Associate Teaching Professor, Dance New York School of Ballet; Carnegie Mellon, 1988-

JUDITH CONTE, Teaching Professor, Dance - B.F.A., University of Wisconsin/Milwaukee; Carnegie Mellon, 1978-

TOME COUSIN, Professor, Dance - M.F.A., Long Island University; Carnegie Mellon, 2011-

KAJA DUNN, Associate Professor, Anti-Racist and Culturally Competent Practice - M.F.A., Regent University; Carnegie Mellon, 2022-

RICK EDINGER, Associate Professor, Music Theatre - M.A., City University of New York: Hunter College; Carnegie Mellon, 2018-

MELINDA ESHELMAN, Associate Professor, Costume Design - M.F.A., Carnegie Mellon University; Carnegie Mellon, 2017-

JANET MADELLE FEINDEL, Professor Emerita, Voice/Alexander - M.F.A., Carnegie Mellon; Carnegie Mellon, 1996-

KRISTI GOOD, Assistant Professor, Dramaturgy - Ph.D., University of Pittsburgh; Carnegie Mellon, 2021--

KYLE HADEN, Associate Professor, Acting – M.F.A., Columbia University; Carnegie Mellon, 2016–

ROB HANDEL, Professor, Dramatic Writing – M.F.A., Brown University; Carnegie Mellon, 2009–

HUGH HANSON, Associate Teaching Professor, Costume Production – M.F.A., University of Hawaii at Manoa; Carnegie Mellon, 2015–

JED ALLEN HARRIS, Associate Teaching Professor Emeritus, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

KEVIN HINES, Associate Teaching Professor, Production Technology & Management – M.F.A., Yale University; Carnegie Mellon, 1998–

GARY KLINE, Teaching Professor, Voice – B.F.A., Carnegie Mellon; Carnegie Mellon, 1990–

GREGORY LEHANE, Professor Emeritus, Directing – M.F.A., Carnegie Mellon; Carnegie Mellon, 1991–

CINDY LIMAURO, Professor, Lighting Design – M.F.A., Florida State; Carnegie Mellon, 1987–

GARY LOGAN, Professor, Voice & Dialects – M.F.A., American Conservatory Theater; Carnegie Mellon, 2016–

JUSTIN LUCERO, Assistant Professor, Directing – M.F.A., University of Essex, East 15 Acting School; Carnegie Mellon, 2019–

BARBARA MACKENZIE-WOOD, Raymond W. Smith Professor Emerita, Acting – M.F.A., Carnegie Mellon; Carnegie Mellon, 1986–

ANTHONY MCKAY, Associate Professor, Acting – B.F.A., Carnegie Mellon; Carnegie Mellon, 1985–

CATHERINE MOORE, Teaching Professor, Movement – M.F.A., University of Cincinnati, College-Conservatory of Music; Carnegie Mellon, 2000–

ANNE MUNDELL, Professor, Design – M.F.A., Brandeis University; Carnegie Mellon, 1989–

RYAN PRENDERGAST, Assistant Teaching Professor, Music and Drama/ Dramaturgy – Ph.D., University of Illinois, Urbana-Champaign; Carnegie Mellon, 2022–

JOE PINO, Associate Professor, Sound Design – M.F.A., University of Virginia; Carnegie Mellon, 1999–

NICA ROSS, Associate Teaching Professor, Video and Media Design – M.F.A., NY Bard-International Center of Photography; Carnegie Mellon, 2016–

BRIAN RUSSMAN, Associate Teaching Professor, Costume Production – M.F.A., Ohio State University; Carnegie Mellon, 2009–

TINA SHACKLEFORD, Teaching Professor – M.F.A., University of California, San Diego; Carnegie Mellon, 2004–

LAWRENCE SHEA, Associate Professor, Video and Media Design – M.F.A., Massachusetts College of Art; Carnegie Mellon, 2010–

ANDREW SMITH, Associate Professor, Acting – M.F.A., University of California, San Diego; Carnegie Mellon, 2014–

LISA VELTEN SMITH, Assistant Professor, Voice – M.F.A., University of California San Diego; Carnegie Mellon, 2019–

AUSAR STEWART, Assistant Professor, Voice – MFA, York University; Carnegie Mellon, 2019–

ROBERT THOMSON, Associate Professor, Lighting; Carnegie Mellon, 2014–

SUSAN TSU, Bessie F. Anathan Professor, Costume Design – M.F.A., Carnegie Mellon, 2003–

DON WADSWORTH, Professor Emeritus, Voice & Speech – M.F.A., University of Pittsburgh; Carnegie Mellon, 1989–

BRIA WALKER-RHOZE, Assistant Professor, Acting – M.F.A., Acting, National Theater Conservatory; Carnegie Mellon, 2023–

KAF WARMAN, Teaching Professor, Movement – M.F.A., Goddard College, Ecole; Carnegie Mellon, 1996–

CHELSEA WARREN, Associate Professor, Scenic Design – M.F.A, Costume & Scenic Design, Northwestern University ; Carnegie Mellon, 2023–

KIM WEILD, Associate Professor, Directing – M.F.A., Columbia; Carnegie Mellon, 2017–

MISO WEI, Assistant Teaching Professor of Stage and Production Management – M.F.A., University of California, San Diego; Carnegie Mellon, 2020–

TJ YOUNG, Associate Professor, Dramaturgy – M.F.A., Texas State University; Carnegie Mellon, 2022–

BETH ZAMBORSKY, Associate Teaching Professor, Scenic Art & Drawing – B.S., La Roche University; Carnegie Mellon, 2003–

School of Drama Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

54-011 Introduction to Alexander Technique

Fall: 1 unit
TBD

54-012 Warmup

Spring: 1 unit
Drama majors only. Freshman Acting Warm Up is a three-day-a-week course which is designed to help the actor prepare mentally and physically for daily training and/or rehearsal. The preparations are based in yoga exercises and are meant to help the actor gain a greater self-awareness, fuller breathing, a greater degree of being centered, and focused on the immediate moment. Prerequisite: 54-011

54-101 Acting I

Fall: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is open to Drama majors only.

54-102 Acting I

Spring: 10 units
A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Drama majors only. Prerequisite: 54-101

54-103 Speech I

Fall: 4 units
(Speech I) The course introduces students to the pronunciation of the sounds of Standard American English pronunciation as presented by Edith Skinner in her textbook SPEAK WITH DISTINCTION. The International Phonetic Alphabet is used to introduce the students to a distinct symbol for each vowel, diphthong and consonant sound. This process will strengthen the student's placement of sounds and will help to illustrate and control regional characteristics. The work is applied to regular individual presentations of various texts. Phonetic transcription is required of class participants throughout the course. Written accuracy of the sounds are required and assigned regularly. This course is open to first year Acting majors who have been accepted to the School of Drama only.

54-104 Speech I

Spring: 6 units
The Spring course continues to develop the foundational work from the previous term. This includes the identification and pronunciation of the sounds of Standard American English. Students will study the physical placement and pronunciation of each sound in isolated applications. The International Phonetic Alphabet (IPA) has been introduced and will continue with further diphthong and triphthong sounds and symbols. Further study will involve strong and weak forms of words, linking 'r' sounds and syllabic consonants; students will apply the advanced speech work to challenging extravagant material as well as exercises with commonly mispronounced words. Prerequisite: 54-103

54-105 Voice for the Stage I

Fall: 5 units
Introduction to basic speaking voice and Alexander Technique work. Actors explore building a vocal preparation employing the principles of the Alexander for actor's speaking voice through explorations that help develop awareness of the head, neck torso relationship and the movement of the spine; vocal release, breath support, stamina. range, use of resonators and the application to text. Actors learn to identify components of healthy and unhealthy voice usage, basics of vocal anatomy and strategies for maintaining vocal health. Writing exercises are employed to help actors connect the voice to creativity and imaginative, essential for the actor's development.

54-106 Voice for the Stage I

Spring: 5 units
Introduction to basic speaking voice and Alexander Technique work. Actors explore building a vocal preparation employing the principles of the Alexander for actor's speaking voice through explorations that help develop awareness of the head, neck torso relationship and the movement of the spine; vocal release, breath support, stamina. range, use of resonators and the application to text. Actors learn to identify components of healthy and unhealthy voice usage, basics of vocal anatomy and strategies for maintaining vocal health. Writing exercises are employed to help actors connect the voice to creativity and imaginative, essential for the actor's development. Prerequisite: 54-105

54-107 Movement I

Fall: 4 units
This course serves as a foundation for all future movement studies. Kinesthetic awareness and responsiveness is developed through the introduction of the Viewpoints method of physical training. The importance of physical expressivity and specificity in storytelling is achieved by the creation of physical movement based compositions. This is a required course for all first year undergraduate Acting and Musical Theatre and Directing students.

54-108 Movement I

Spring: 4 units
This course is designed to continue the physical actor training sequence begun in the previous semester by introducing new methodologies and working vocabularies. This course examines and explores the use of the human body as an expressive artistic instrument of communication. Concepts of the body in relation to Time, Space, Weight, and Energy will be explored. This is a studio course in which learning is experiential. In addition to daily class activities and exercises, assignments will include a written test and solo presentations/performances. Admission to this course fulfills a requirement for first year undergraduate acting and music theatre majors Prerequisite: 54-107

54-109 Dramaturgy 1: Approaches to Text

Intermittent: 9 units
This course is an introduction to dramaturgical analysis of a play; the goal of this course is to provide students with a number of text analysis "tools" to use in understanding plays for production.

54-110 Text for Actors

Fall: 2 units
This class is in conjunction with Acting I in the School of Drama. The actor/director learns how to investigate the written text and translates it actively for performance.

54-111 Text for Actors

Spring: 2 units
This class is in conjunction with Acting I in the School of Drama. The actor/director learns how to investigate the written text and translates it actively for performance.

54-115 Rhythmic Exploration

Spring: 1.5 units
Optional course.

54-117 Design Collaboration Project

Spring: 3 units

This course is intended to provide students with hands-on experience in the process of collaboration on a design for a production. Students in the course will work in teams to design a hypothetical production of a given play.

54-119 Vocal Technique

Fall: 1 unit

Singing technique for first-year Music Theatre students.

54-121 Directing I: A Director's Mindset

Fall: 9 units

A discovery of the director's mindset. Through discussions, readings, exercises, projects and explorations, this course is intended to give the aspiring director a foundation for the continual investigation into multiple forms of expression that might feed the director's imagination and toolbox.

54-122 Directing I: A Director's Preparation

Spring: 9 units

A continuation of the previous semester focusing on a director's preparation.

Prerequisite: 54-121

54-123 Dance Technique I: Physical Mechanics and Anatomy

Fall: 5 units

This course uses Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Permission of instructor.

54-124 Dance I: Applying Dance Technique

Spring: 5 units

This course continues Classical technique (Ballet) to build body placement, alignment and muscular strength and flexibility. Designed to help the student develop a way of learning how to work and train for any dance form. This technique is the basis of the choreography in American musical theater. This course is for Music Theatre majors only. Prerequisite: 54-123 and permission of instructor.

Prerequisite: 54-123

54-125 Music Skills I

Fall: 4 units

The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing. For School of Drama MT students only.

54-126 Music Skills II

Spring: 4 units

The students explore the basics of music theory, which includes intervals, rhythm, notation and musical vocabulary. Emphasis is on acquiring these basic skills through sight singing.

Prerequisite: 54-125

54-134 Writing for Television

Spring: 9 units

Students will write an original pilot, focusing on structure, character, and an analysis of what makes great TV.

54-135 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed

Fall and Spring: 6 units

For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of *The Disembodied Hand That Fisted Everyone to Death - the Musical!*, *Blatantly Blaine*, *Pop Punk High*, *Donny and Kelly Save the Slumber Valley ASPCA*, and more - all produced and reviewed in NYC.

54-151 Stagecraft

Fall and Spring

The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools and amp; equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-152 Stagecraft

Spring: 13 units

The stagecraft class is designed to provide an introductory level of technical training in all the theatrical technical disciplines over the course of two semesters. The intent is to produce people who can capably fill roles on production crews and perhaps serve as an assistant to the head of the crew. Course content will cover materials, tools equipment, procedures, safety and operations for Carpentry, Props, Paints, Media, Costumes, Lights, Sound, Rigging, and Run Crew. As well as providing opportunity and experience to grow as technicians, this content will also help establish a foundation to begin the process of becoming managers and designers. As craft skills are often best communicated in a master/apprentice environment this course is set up as a mentored practical experience. This course requires significant additional scheduled time on evenings and weekends for crew calls, which are an important element of the course.

54-157 Production Science

Fall: 6 units

Students in the Production Science course are exposed to the very fundamentals, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. Drama Design/Production majors only, or with instructor permission.

54-158 Production Planning

Spring: 6 units

Students in the Basic PTM course are exposed to the very fundamentals, of entertainment technology. The intent is to provide the absolutely strongest beginning for all the work to come, to provide a solid foundation for students and instructors to build upon. Production professionals routinely perform organizational tasks. In order to be able to meet that challenge, students will need to build a toolkit of information and procedures. That toolkit will be comprised of knowledge of the kinds of parameters and techniques that are normally selected, the indices that parameters and techniques are evaluated against, and many of the wide range of issues that might point a manager toward one decision or another. There also exists an entire pantheon of information that people typically learn "on the job." Activities and information presented in this course are designed to try to expose students to as much of this on the job type development as possible with the goal of leapfrogging them past the bottom rung of the workplace ladder. PREREQUISITES: Declared Design/PTM focus in the School of Drama FOR: First Year Undergraduate Students

54-159 Production Practicum

Fall: 6 units

Hands on experience in most aspects of installing and running a production.

54-162 Introduction to Costume Design

Spring: 6 units

A rigorous introductory studio course for newly declared School of Drama Costume Design Sophomores in their fourth semester of matriculation. Basics of the design process are covered as well as drawing, sculpture, semiotics, play and character analysis, research and character building are explored. An intensive collaboration project with students of other design disciplines comprises the second half of the course. PREREQUISITES: Basic Design-54-171 and 54-172. All others: interview/portfolio review and instructor permission. FOR: 3rd semester Sophomore Costume Designers and students outside of School of Drama. IDEATE. Prerequisites: 54-171 and 54-172"

Prerequisites: 54-172 and 54-232 and 54-171 and 54-231

54-163 Production for Non Majors

Fall: 6 units

Non-major involvement in a Schools of Drama production or classroom project.

54-166 Introduction to Sound Design for Theatre

Spring: 6 units

Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Prerequisites: Basic Design and Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.

Prerequisites: 54-172 and 54-171 and 54-232 and 54-231

54-167 Acting for Directors I

Fall: 10 units

Acting I for Director BFA students.

54-168 Acting for Directors I

Spring: 10 units

A knowledge and beginning understanding of the components of acting. Basic exercises, improvisations and prepared work in relaxation, concentration, imagination, communication. The ability to create the reality of a given situation in theatrical terms. Craft fundamentals in preparation for scene study. The beginning development of the students creative resources. This course is for Directing students only.

54-169 Studiocraft 1

Fall: 13 units

The studiocraft course provides beginning level instruction in Drawing, Hand Drafting, and CAD Drafting.

54-170 Studiocraft 2

Spring: 8 units

Using the basic skills learned in the first semester, we will develop better and explore the use of basic drafting processes to solve more complex problems. The conventions of drafting do not change with the different types of drawings so line weight, clarity, neatness and organization will continue to be emphasized. We will also begin to discuss ways to improve the cosmetics of draftings. As before, classes will consist mostly of lecture and demonstration. Some class sessions will be dedicated to working on assigned projects, generally one class meeting per project.

Prerequisite: 54-169

54-171 Basic Design 1

Fall: 6 units

A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: First Semester Design/PTM Undergraduate Students only.

54-172 Basic Design 2

Spring: 6 units

A year-long studio course that explores the principles and elements of design utilizing discreet exercises and projects first semester. Research and reports expose the students to designers, theatres and artists of note in the world. Second semester focuses on the semiotics of the visual and aural aspects of theatrical design. Projects fold in each of the disciplines of scene, costume, lighting, sound and media design. PRE-REQUISITE: Declared Design/PTM focus in the School of Drama. FOR: Second Semester Design/PTM Undergraduate Students only

Prerequisite: 54-171

54-175 Conservatory Hour

Fall: 1 unit

A discussion class for first-year Drama students. Open to non-majors interested in declaring a Drama minor.

54-176 Conservatory Hour

Spring: 1 unit

A year-long discussion class for first-year Drama majors. Open to non-majors interested in declaring a Drama minor.

54-177 Foundations of Drama I

Fall and Summer: 6 units

In this course, students receive training in the basic analysis of scripts to determine key elements of structure, plot, characterization, thematic content, theatricality, and aesthetics. In addition, the course provides training in dramaturgical research and writing.

54-179 Making Room: Study of Black American Playwrights

All Semesters: 6 units

This course, a research forum, is an opportunity to investigate, share and analyze the work of Black American Playwrights. Classics from artists like Marita Bonner, Georgia Douglas Johnson and Pearl Cleage are entryways to the dynamic expressions of Black authorship. This course will add to the analysis pool of both classic and contemporary text. Expanding the assembly's general knowledge, students will be invited to share work that sparks their interest as well.

54-183 Documentary Theater

All Semesters: 9 units

Creating theater from real life is as ancient as the art form itself. Yet since the early 20th century, the emergence of "documentary" or "verbatim" theater has opened up new possibilities for theater-makers as artists, investigators, and cultural influencers. This course will introduce you to the theory and practice of documentary theater, as well as its intersections with multimodal oral history and digital storytelling. From Mois and #233;s Kaufman's The Laramie Project to Adrian Jones's Pittsburgh-based app Looking Glass, topics will include history, ethics, and practical methodologies including interviewing and creative interpretation of journalistic information. By the end of this course, you will create and iterate on a short, original piece that feels important to your work and inquiry in the world.

54-184 Dramaturgy 2: Introduction to Production Dramaturgy

Intermittent: 9 units

Dramaturgy 2 introduces students to the essential tasks and processes that dramaturgs perform on productions of established plays (i.e., plays whose texts are not changing). Students perform text analysis, conduct research, curate and present information, develop and provide critical feedback on production work in progress, and design pre- and post-performance experiences for an audience. This is a writing-intensive course with a high reading load. Dramaturgy 2 is a prerequisite for higher-level courses in the Dramaturgy curriculum.

54-187 Writing the Adaptation for Stage and Screen

Fall: 9 units

Great artists steal. This class is for writers of all skill levels interested in creating an adapted work. We will look at a range of different adaptations and discuss the choices the writers made and #8212; from Stanley Kubrick's film adaptation of Thackeray's picaresque "The Luck of Barry Lyndon," to Sarah Ruhl's dreamlike theatrical retelling of the Orpheus and Eurydice myth. You will leave this class with a toolkit for taking the shape of a story and making it your own, and with the first 10-30 pages of an original adapted work.

54-189 Advanced Writing for Television

Intermittent: 9 units

In this course students will be introduced to the major components of writing for TV, including character and structure, while analyzing genre television and pilot writing. Exercises designed to familiarize students with the tools available to TV writers will be assigned, and over the course of the semester, students will develop an original TV pilot. (Students who have not taken "Intro to TV Writing" need to seek permission from the instructor, but don't let that deter you!)

Prerequisite: 54-134

54-190 Creating the Choreopoem

Spring: 9 units

In this course, we will focus on the playwriting genre created by Ntozake Shange - The Choreopoem. A choreopoem may be briefly defined as storytelling with movement, an act of rebellion. Other elements that classify a play as a choreopoem include dance, rhythm, music, and poetry. During the course, we will be reading various choreopoems and drawing different techniques from each one. Techniques such as writing workshops, in-class discussions, and freewriting will guide you into crafting a full-length, original choreopoem. As we write, we will reflect on who came before us: playwrights who paved the way, as well as our own ancestral heritage. We are because they were.

54-191 Acting for Non-Majors

Fall and Spring: 9 units

This class is designed for non-acting majors and introduces the student to the basic principles of acting, character study and improvisation. One semester course.

54-192 Acting Ensemble for Non-Majors

Fall and Spring

This course offers an opportunity to work with undergraduate student directors on their projects, which will widely range in material (e.g. adaptations of literature to television scripts to musical theatre). Directors will hold auditions in the first week of school for their projects, and the actors who are cast will then have the opportunity to enroll in this class. Depending on the project, actors may be cast for one mini or two, potentially working with more than one director. Actors will be required to attend rehearsals outside of class up to 5 hours a week, and to attend class when showings happen. Audition required at the beginning of the semester. Admittance to class by permission of professor. If you are interested, add yourself to the waitlist.*****

54-193 Acting for Non-Majors: Improv

Intermittent: 9 units

This course will introduce students to the history and components of improvisational performance. Students will explore short and long form improv styles and work in teams to create original, in-the-moment performances. We will also investigate real-world applications of improv techniques and imagine a future rooted in cooperation. A desire to work together is essential for this class.

54-195 Creative and Dramatic Writing for Engineers

Fall: 9 units

This course is centered on learning dramatic structure for storytelling while cultivating a sense of creativity utilizing the written word. Throughout this course, students will translate these new skills into technical writing to relay information in a clear, effective, and compelling way. Prerequisite: 76-101

54-196 Harvesting Personal Narratives: A Writing Workshop

Spring: 9 units

In this welcoming writing workshop, we will work to discover, shape, refine, and share stories sparked from personal experience. Students can expect in-class writing exercises, tools for finding story-worthy moments, and an investigation of varied works inspired by lived experiences, as we explore how to take a personal narrative and translate it into a shareable story ready for a reader and/or viewing audience. The course will consider predominantly contemporary works from a variety of mediums including plays, screenplays, short films, television pilots, and web series. Working towards a final in-class reading of student work, students will leave this course with a new, creative writing piece generated from a dynamic combination of self exploration and in-depth revision. Students from all writing backgrounds and experience levels are welcome. Everyone has a story to tell. Come harvest yours this fall.

54-198 Plays With Words: Exploring Language-Driven Theater

Fall and Spring: 9 units

This course will provide students with an understanding of the category of plays that use language as their main engine of storytelling. Students will learn to identify and analyze the conventions of language plays, as well as practicing techniques to write their own. Some of the elements of language plays discussed in this course include plays with non-naturalistic language, emotionally expressive language, and action-driven language. The course will culminate in a final project in the form of a completed, full-length language play.

54-200 Dramaturgy Forum

Fall and Spring: 1 unit

Programmed and taught by senior students in the Dramaturgy program, this course is required for all Dramaturgy majors and meets once per week to discuss issues and topics of significance to the dramaturgy community.

54-201 Acting II

Fall: 12 units

Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques. Prerequisites: 54-102 and 54-101

54-202 Acting II

Spring: 12 units

Scene study: the fundamental techniques needed to participate in the developing conflict within the imaginary world. Character building through unfamiliar behavior and beliefs; relationships; language. Spring semester: The use of classical texts and ensemble playing. The deepening of the actors inner resources to be supported by the craft techniques. Prerequisite: 54-201

54-203 Voice and Speech II

Fall: 4 units

The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare's plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work. Prerequisites: 54-103 and 54-104

54-204 Voice and Speech II

Spring: 4 units

The actors take a more concentrated approach to elevated text. The course focuses on the effective production of classical text. The warm up sessions are geared towards preparing the student actors for the extravagant language from Shakespeare's plays and sonnets. Meter, imagery and further specific text work is also employed to encourage each student to find clear shape in the work. A repertoire of at least five classical monologues will come from the course work. Prerequisites: 54-203 and 54-103 and 54-104

54-205 Dance II: Pillars to Build Dance Technique

Fall: 3 units

This course is designed to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor Prerequisites: 54-124 and 54-123

54-206 Dance II: Pillars to Build Dance Technique

Spring: 3 units

This course continues to build on the technical foundation, work habits and professional behavior established in Ballet I. The material presented expands the classical dance vocabulary to the next level of difficulty. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-205

54-207 Movement II

Fall: 4 units

Movement II is a Lecoq-based course that weaves together three approaches to physical development: movement foundations, mime, and mask. Foundational work covers the basic principles and practices required to gain a solid physical technique as an actor: grounding, centering, balance, tension/relaxation, tempo variance, listening, levels of play, physical imagination, etc. Mime studies of dramatic action sequences such as pulling, pushing, climbing, throwing and classical mime illusion encourages economy and precision. Mask work conceals the face and reveals the body, forcing the actor to rely less on facial expressions and focus more on the stories being projected by the body. The main objective of this course is to encourage a disciplined mastery over bodily control and physical expression that has a direct application to playing a variety of theatrical styles. Limited to Acting/MT majors only. Prerequisites: 54-107 and 54-108

54-208 Movement II

Spring: 3 units

This term is divided between two classic physical forms: Commedia dell'Arte and Clowns. In the first half of the semester students wear the half-masks of the archetypal Commedia characters (Harlequin, Pantalone, et al), to learn their psychology and physicality, improvise on historical and contemporary scenarios, and apply Commedia technique to modern comedy. Commedia dell'Arte gives them the tools to tackle physical comedy from any era, past or present. In the second half of the term students discover their personal Clowns. This clown has nothing to do with the American Barnum and amp; Bailey Circus clown; this is not a character or caricature, but rather a revelation of the clown each student hides under the mask of adulthood. Discovering this clown gives them all a way to laugh at themselves, to uncover what makes each individual uniquely funny; it also lets them see how we only laugh at truth and in the personal material lies universal humor. Inside this freedom is the technique to know what's funny and why, and the ability to apply these rules in comedy."

Prerequisites: 54-207 and 54-108 and 54-107

54-209 Voice and Speech II: Practicum

Spring: 3 units

TBA

54-211 Actor Dance II

Fall: 3 units

This course introduces the basic, fundamental vocabulary of Classical technique (Ballet) to train the body in proper alignment, placement, and muscular strength. Course closed: Only for Acting majors in Drama.

Prerequisite: Permission of instructor

Prerequisites: 54-101 and 54-102

54-212 Actor Dance II

Spring: 3 units

Beginning Ballet. A continuation of Classical technique (Ballet) and a unit of social dance styles, waltz, polka, foxtrot, tango, swing. Course closed: Only for Acting majors in Drama.

Prerequisites: 54-101 and 54-102 and 54-211

54-213 Singing for Actors II

Fall: 3 units

The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.

Prerequisites: 54-102 and 54-101

54-214 Singing for Actors II

Spring: 3 units

The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.

Prerequisites: 54-101 and 54-102

54-216 Technical Solutions from the OSF

Spring: 3 units

This course is an introduction to planning for repertory theater using the Oregon Shakespeare Festival as a model. Students will explore topics including the inherent tensions between time and space created by a rep, interdisciplinary technical design, automation, collaborating with designers, and common rep pitfalls. By course end, students will not only have a working analysis of the inner machinations of a repertory model, but also a deeper understanding of regional theater art making overall.

54-217 Jazz II

Fall: 2 units

This course is designed to incorporate the strength of classical dance technique to a jazz dance style. Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor

Prerequisites: 54-123 and 54-124

54-218 Jazz II

Spring: 2 units

This course continues to incorporate the strength of classical dance technique to a jazz dance Training the body in a variety of contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, using body isolations and rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.

Prerequisite: 54-217 and Permission of instructor

Prerequisite: 54-217

54-219 Special Topics: Music Theater History and Repertoire

Fall: 6 units

This course is a survey of musical comedy and musical theatre performances throughout history. Often considered a quintessential American theatrical form, we will also consider what "musical theatre" or "musical drama" means beyond the borders of the United States. The course will primarily focus in the time frame of 1860-present. We will examine the historical background, development and evolution of form, as well as impact and proliferation of this performance style. The class will look at all levels of musical theatre: music/lyrics, book, production, direction, choreography, marketing, popularity, cultural impact, globalization, etc. The course will involve lecture-based, discussion-based, and project-based styles of engagement. For this section of the course, students will engage in practice-based learning to build a diverse repertoire of songs. They will also continue to reinforce the principals of music theory learned in the first year by learning a new piece of repertoire every week that coincides with said week's topic.

Prerequisites: 54-500 or 54-281

54-220 Acting A Song

Spring: 4 units

This class is for Music Theatre majors only. This class explores the personal relationships between performer and song. Exercises include Class Interrogation, Story Telling, and Text Analysis. Based primarily on the personal experience the actor brings to the text, rather than technical aspects. Acting a Song is the prerequisite for Cabaret class.

Prerequisite: 54-500

54-221 Directing II: In the Studio

Fall: 9 units

Directing II This is a fall-semester course for 2nd-year Directing students and others with special permission introducing the fundamentals of the director's craft: text analysis; the concept of Action and amp; Change, directors units and amp; transitions) Visual Vocabulary and amp; Staging. Tools including planes, levels, body positions, composition, picturization, emphasis and amp;movement, and the ground plan. Work includes unscripted exercises, scene breakdowns, detailed character analysis, and a final 7 to 10 minute devised performance

54-222 Directing II: In The Room

Spring: 9 units

A continuation of the work done in the first semester of Directing II. This course is for Directing sophomores and BXA Directing students only.

Prerequisite: 54-221

54-223 Tap II - Rhythmic Technique/Foundational to Complex

Fall: 2 units

This course trains the student to develop a comfort level to execute percussive sounds, in a variety of percussive rhythmic patterns while applying the technical foundation of alignment and placement from classical technique. Course closed: Only for Music Theatre majors in Drama.

Prerequisite: Permission of instructor

Prerequisites: 54-124 and 54-123

54-224 Tap II: Rhythmic Technique/Foundational to Complex

Spring: 2 units

This course continues to technically train the student in a variety of percussive rhythmic patterns. Course closed: Only for Music Theatre majors in Drama.

Prerequisite: 54-223

54-225 TD Case Studies

Fall: 3 units

This course will through a weekly round table discussion look at examples of real-world experiences involving technical direction concerns, obstacles, and dilemmas. Each week the class will be given a situation or example that occurred in the past during production of a Pittsburgh Civic Light Opera summer season. The students mediated by the instructor will brainstorm and discuss reactions and solutions to these problems. Realizing that often there are many solutions to the same TD problems depending on any given situation, not only will the discussion look at what was done at the time of the example but how other methods might be weighed against those used. Once the group comes to a consensus on the week's issue the students will be responsible for outlining the process to correct the problem, avoid future similar concerns, or alter the contributing situations. This outline might be in the form of mechanical drawings, excel files, word docs, or actual outlines.

54-227 How to Write a Shakespeare Play

Fall and Spring: 9 units

There are dozens of books that present a set of rules for writing a play, but not one of them will result in a play like those written by the world's most beloved playwright. This is madness. Whom should we take as a model if not Shakespeare? Can we invent an alternative set of rules that will permit mad shifts of tone, disregard for unities of time and place, stages shared by people from different social classes, inside-out characters (driven by individual psychology) alongside outside-in characters (driven by archetypal imperative), bad puns, dirty jokes, storms, slapstick, and the raising of unanswered (and unanswerable) questions? In this course, we will ransack our colleague Shakespeare's work to find strategies we can steal and reshape for our own purposes, through a series of writing projects on the level of the line, the speech, the scene, the act, and the play.

54-229 The Biz - In Practice

Fall: 4 units

Students will assess and investigate their personal professional path using the information and experiences from The Business of Acting course.

54-230 Make-Up for Designers

Spring: 6 units

This course is structured as a lecture/demonstration and lab employing and exploring the principles of stage makeup, the variety of materials available and the practical application of these materials. The course is designed to provide the student with a working knowledge of broad-based application procedures, materials and techniques. We will also explore the principles of characterization allowing for the development, planning, and execution of effectual character makeup designs. The student should also be able to determine the stage-worthiness of a makeup application and how light will influence its appearance.

54-231 Design for the Stage

Fall: 6 units

This course is divided into four minis to introduce the student to the design process for costumes, lighting, scenery and sound. For Drama majors only, or instructor permission

Prerequisites: 54-169 and 54-170 and 54-171 and 54-172

54-232 Design for the Stage: Lighting

Spring: 4 units

This course is an introduction to the process of lighting design. Students will engage in various hands-on light lab exercises and group projects to explore the physical properties of light in storytelling. Discovery and experimentation are encouraged. Students will begin to build a process for visualizing a play through the principles of design, interpreting a text, and communicating ideas.

Prerequisites: 54-171 and 54-170 and 54-172

54-233 Acting For Directors II

Fall: 12 units

Acting II for Directors

54-234 Acting For Directors II

Spring: 12 units

Acting II for Directors

54-237 Scenic Painting I

Fall: 6 units

This is a one semester studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/exterior scenes, the human figure, still life objects.

54-238 Scenic Painting II

Spring: 6 units

This is a studio course in the foundations of scenic painting for theater and related fields. Students will complete projects that address the following topics: preparation of and paint techniques for both soft goods and hard covered surfaces, drawing and painting to scale, representing textures in both 2 and 3 dimensions, and color mixing. Subject matter changes often and may include: architecture, natural and man-made textures, drapery, interior/ exterior scenes, human figure, still life objects.

54-239 History of Architecture and Decor 1: Ancients to Gothic

Fall: 6 units

This course is a survey of architecture, furniture and interiors from ancient times to the Gothic period. A lecture/slide course, the discussion of architecture is done with reference to social, political and economic history.

54-240 History of Architecture and Decor 2: Renaissance to the 21st Century

Spring: 6 units

This course will cover the styles and movements of architecture, furniture and to a lesser degree, the decorative arts, from the Italian Renaissance to modern day architecture in the West as well as the major Chinese, Indian and Islamic periods in the East. Discussions will include the social, economic, religious and political history of each period in as much as it helps illuminate the reasoning behind the visual nature of its architecture.

54-242 Improvisation

Spring: 2 units

This course is for Sophomore Actors only. This course not only sharpens their skills as ensemble performers, but also allows for more playfulness, creativity and exploration, cultivating risk-taking and a certain abandon. The course concentrates on non-verbal psychological improv, helping actors achieve a kind of physical truth and spontaneity, while becoming aware of the importance of the body in conveying information.

Prerequisites: 54-102 and 54-101

54-245 Who Wore What: When, Where, and Why

Fall: 6 units

This year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-246 Who Wore What: When, Where, Why II

Spring: 6 units

The 2nd part of this year-long course surveys the development of garments in the Western World from ancient civilizations to the first half of the 20th century. We will look at the progression of the shapes and forms that aesthetically define the clothing of each period, while also exploring the broader relationship of costume to culture and society through history. The course will comprise visual presentations of the art of each period, especially pertaining to representations of clothing, along with research projects, quizzes and exams.

54-247 Dramaturgy 6: In Company

Intermittent: 9 units

Dramaturgical work in a theatre company extends far beyond individual productions. In this course students get hands-on practice in season planning, writing fundraising text, writing marketing text, and public speaking - all responsibilities that are typically but less visibly part of a dramaturg's job description. This course provides good grounding for a future in artistic leadership. Required for dramaturgy and directing majors; open to non-majors with instructor permission.

Prerequisite: 54-184

54-249 Stagecraft II

Fall: 14 units

Stagecraft II presents advanced shop skills and beginning department head skills for Scenery, Lighting, and Costumes. This course will require additional time during the evening and on weekends. Prerequisites: Stagecraft I (two semesters) OR Instructor Permission

Prerequisites: 54-152 and 54-158 and 54-151

54-250 Introduction to Scenic Design

Spring: 6 units

This course will introduce students to the principles and methods of designing scenery using the development of ideas based on a text.

Prerequisites: 54-232 and 54-169 and 54-172 and 54-171 and 54-231

54-251 Automated Lighting Maintenance

Spring: 2 units

Hands-on exploration of the operation and maintenance of equipment that falls into the category of automated lighting.

54-252 Introduction to Lighting Design

Spring: 6 units

Students explore the physical properties of light in various design applications and develop a process of storytelling that involves analysis, research, exploration, questioning, problem solving and implementation of a successful design product. Prerequisite: Design for the Stage, or instructor permission.

Prerequisites: 54-232 and 54-231

54-254 New Play Development

Spring: 6 units

This course will serve as an intensive workshop for new plays in collaboration for playwrights and dramaturgs. Playwrights will present pages from a piece they are currently developing, utilizing other playwrights and dramaturgs as their "cast" for the purpose of hearing the play aloud. The dramaturg paired with each playwright will facilitate a feedback session, built from conversation with the playwright, to elicit feedback from those in class that will aid in the creation of future drafts.

54-255 New Play Collaboration for Actors

Fall: 1 unit

TBA

Prerequisite: 54-101

54-256 Dramaturgy 3: New Play Dramaturgy

Intermittent: 9 units

This course focuses on the dramaturg's collaborative relationship with a playwright during the creation of a new play. During the first mini, dramaturgs work on close reading of multiple drafts of a new play, tracking changes and assessing their impact, and developing healthy collaborative processes. During the second mini, playwrights join the course; each dramaturg is matched with a playwright and puts those new skills into practice. Required for dramaturgy majors; no non-majors will be admitted to this course in fall 2020.

Prerequisites: 54-184 and 54-109

54-257 Directing: Production II

Fall: 6 units

Assignments as stage manager or assistant director.

54-258 Directing: Production II

Spring: 6 units

Assignments as stage manager or assistant director for the Rauh Studio and Chosky Theatres.

54-264 Welding

Fall and Spring: 4 units

An introduction to the two most commonly used welding processes used in the entertainment industry. GMAW (MIG), and GTAW (TIG). Welding safety, equipment setup and basic welding techniques will be covered. This is a required course for Drama Technical Direction majors. Open to non-majors if space is available.

54-265 Advanced Fabrication 1

Fall: 6 units

This class sets forth to gain a comprehensive understanding of the various tools found in a well-equipped fabrication shop. Shop safety will be emphasized at all times and rigorously promoted per tool. Understanding the differences between tools and when to choose each will be a constant theme. Exploring the various ways of achieving a certain result but with different tools will be a recurring theme. Since most shops use tools for multiple applications, understanding how various materials relate to various tools will be discussed in detail. For TDs only. The first task will be to do an overview of all of the common tools used for woodworking and metalworking. Then we will go through the shop tool-by-tool and make sure everyone understands what the tool was designed for, how it is used, and how it may be utilized for alternative uses.

54-266 Stage Management: Cue Lab

Fall and Spring: 4 units

Required for Production Management / Stage Management majors. Practical experience in cue calling from a variety of sources and with various tools and methods.

54-267 Conceptual Sound Design

Fall: 9 units

Students explore the unique qualities of audio as a design element and the development of a design process through script analysis. Emphasis on the creative application and utilization of the studio in sound shaping and soundscape design. PREREQUISITE: 54-166 Introduction To Sound Design for Theater, 54-231 Design For The Stage. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.

Prerequisite: 54-166

54-268 Collaborations in Organized Sound

Fall: 3 units

Both music and sound design are defined by the presence of a human hand in the organization of sound. This course explores what lies at the intersection of music, technology and sound design, as well as the challenge of writing for an experiential, time-based art. Using compositional and dramatic writing techniques in conjunction with the creative application and utilization of studio techniques, field recording, editing and sound manipulation, the student will explore this interstitial landscape. Drama majors have priority, however this course is also open to Music Technology majors and minors, or with permission of instructor.

Prerequisites: 54-267 and 54-166

54-269 Studiocraft II

Spring: 3 units

A continuation of 169/170, this course introduces applied drafting practices, perspective drafting, 3D CAD modeling, model building, and other graphical skills. Prerequisites: 54169 and 54170 OR Instructor Permission

Prerequisites: 54-171 and 54-172

54-271 Technical Management

Fall: 6 units

Required for all sophomore Design and PTM students. This class establishes a set of standards for creative project management and introduces students to several software packages that can be utilized within these tasks.

Prerequisites: 54-158 and 54-157

54-272 Scenic Fabrication and Installation

Spring: 6 units

The Scenic Fabrication and Installation course consolidates and builds upon material presented in the first semester of Basic PTM and in the three semesters of Stagecraft class. Whether they intend to pursue careers as technicians, engineers, or managers students much understand how scenery is built and what is involved in the assembly of the scenery in the theatre. Throughout the semester students will explore the materials and equipment used by all kinds of professionals in the fabrication industry. Through this exploration students will become conversant with the kinds of properties, and the advantages and disadvantages of many different items. Along with this exploration is a concurrent investigation of entertainment industry accidents. This material is valuable in how it contextualizes the kind of work students will be involved in, and helps to drive home the very real consequences of errors pertaining to scenery. In the classroom and in lab students in this course will develop their knowledge and processes for building scenery. The course has three basic units. The beginning of the semester focuses on building materials and on tool use. Through the center of the semester course material focuses on traditional scenery practices. The end of the semester material addresses rigging systems and scenery rigging practices. Laboratory assignments tied to this course will consist of carpentry assignments in the shop and carpentry and rigging assignments during load in. Occasionally students pursuing a more customized path may have lab assignments in the paint department in the shop and in the electric department during install. All students may receive apprentice assignments in the scenery office.

54-273 Technical Direction I

Fall: 6 units

This course is an exploration of techniques and practices of the Technical Director. The class has three main components: classroom presentation of School of Drama production technical direction process, classroom lectures centering on TD process, and project work. Over the course of the semester, students will work on two productions as paper projects. This is an opportunity to have a somewhat less stressful pass through a show, completing estimates, schedules, and drawings designed to help establish a professional foundation for the student as a technical director. All of the course components run concurrently. Prerequisites: 54272 or Instructor Permission

Prerequisites: 54-272 or 54-158

54-274 Seminar in Costume Management

Fall: 4 units

This mini course focuses on the fundamentals of organizational paperwork surrounding costume production and basic operational protocol. The evolution of this paperwork and its usefulness in multiple professional applications is covered.

54-275 History of Sound Design

Intermittent: 3 units

The history of the use of sound in theater from the Greeks to current day including study of the development of the art, significant practitioners and landmark productions.

54-277 Negotiation and Conflict Management

Fall: 3 units

This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and roleplay will be a fundamental part of class activity.

54-278 Stage Management I

Spring: 6 units

This class introduces the student to the work of a stage manager on a theatrical production. Students learn the functions and responsibilities of the stage manager. Also covered: blocking notation, cue organization, rehearsal reports and AEA rules and regulations.

54-279 Embedded Electronics

Fall: 3 units

TBD

54-281 Foundations of Drama II

Fall and Spring: 6 units

In this course students build on the skills of Foundations I to develop acumen in targeted research in support of production. The students learn the "circles of knowledge" technique to provide evidentiary arguments concerning a play script, its author, the historical contexts in which it was written, the theoretical frameworks that may be applied to its interpretations, its production history, and what knowledge is needed to bring its themes to relevance in a modern production. As in Foundations I, there is a great deal of exposure to significant texts, both artistic and philosophical, from theatre history. Registration for this course is limited to Drama majors. All other majors must request the instructor's permission. Prerequisites: 54-178 or 54-177

54-284 Fundamentals of Directing

Fall: 6 units

Fundamentals of Directing is a fall-semester course for Drama Design and PTM sophomores. It is an introductory course that examines some of the basic tools of the director. Emphasis is completely on theatrical work although some elements are applicable to television and film.

54-285 Alexander Technique Tutorials

Fall and Spring: 1.5 units

Half-hour tutorials, individually scheduled per student. Optional for Acting and Musical Theater students.

Prerequisite: 54-101

54-287 Introduction to Lighting Design Skills

Spring: 3 units

Students will gain the basic skills and practical experience to use the lighting industry's primary software programs: Vectorworks and Lightwright. The class will be seminar based and allow focused opportunity to acquire the skills to execute some of the assignments in the Introduction to Lighting Design course. This course must be taken simultaneously with Introduction to Lighting Design (54-252).

54-290 IDEATe: Movement for Animators

Fall and Spring: 4 units

Movement serves as a basis for communication and visual storytelling. This course will provide actual physical movement training so that you may better understand its implications and applications for technology-based usage and your own engagement in the creative process with others. Playful participation, observation, and discussion will allow you to consider how to apply physical movement and movement theory in the areas of Animation and Special Effects, Motion Capture, Game Design, and other technology practices and research. Drawing from a number of methodologies you will explore how the variances of Time, Space, Weight, and Energy affect communication, storytelling, character development and narrative structure. We will examine the ways in which movement conveys psychological intent and emotion. This course is designed for students who may range from having no prior movement training experience to those who have some background in sports, dance or theatrical movement.

54-294 Make-Up for Performers

Spring: 2 units

PREREQUISITE: Acting/MT major in the School of Drama. Basic techniques of stage make-up and their adaptation to theatrical styles.

Prerequisite: 54-102

54-295 Advanced Fabrication 2

Fall: 6 units

Continuation of Ad Fab. For Drama PTM-TD only.

54-297 VMD Systems Studio

Spring: 9 units

This course is designed to augment the conceptual background and technical skills of First year Graduate students and newly declared VMD Sophomores, and others interested in learning about media design for theater and installations. The course reviews foundational readings about media, technology and society and explores the skills used in contemporary media work. Through real-world examples, building custom media servers, experimenting with materials and software, rigging multiple types of display systems and visiting artists - students will learn the best practices for bringing their designs to life. A great deal of technical information will be covered including; video compression formats, projector optics, cueing software, projection mapping and amp; custom surfaces, media servers both custom and professional, networking and control protocols, live camera systems, and stage rigging for projection systems. The class will give students a clearer perspective of the field and help them plan a fulfilling course of study, based on their goals and interests. Class projects range from presentations of research to building media installations over at Studio 201. Required for new VMD Sophomores, 1st Year VMD Grads; open to IDEATe and BXA students; others accepted up to class limit. Prerequisites: 54-231 and 54-232

54-299 Dramaturgy Production:Assistant

Fall and Spring: 9 units

For Dramaturgy majors.

54-300 Dramaturgy Research Hours

Fall and Spring: 6 units

For Dramaturgy majors.

54-301 Acting III

Fall

This is a two-semester course in Acting for Third-Year Actors and amp; MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy, the Greek Chorus, Moliere Comedy and amp; Brecht. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools and amp; perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text and amp; its directed world, and amp; to "fill the Form" believably and amp; passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.

Prerequisites: 54-201 and 54-202

54-302 Acting III

Spring: 5 units

This is a two-semester course in Acting for Third-Year Actors and amp; MTs who will explore performance within directed structure in various non-Fourth-Wall forms of Theatre including: Greek Tragedy. This is not a course that will aspire to provide any "correct" way to play various "styles". Rather, it is a course in which to acquire new tools and amp; perspectives when working in new theatrical worlds. Goals include: to find the appropriate level of external expression to meet the demands of the particular text and amp; its directed world, and amp; to "fill the Form" believably and amp; passionately; to make active choices within a directed framework; to learn to work within industry standards; to learn the nature of the actor's "homework" in a directed framework; to include the Audience in the work.

Prerequisite: 54-301

54-305 Voice for the Stage III

Fall: 5 units

Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.

Prerequisites: 54-106 and 54-105

54-306 Voice for the Stage III

Spring: 5 units

Students explore voice work and various methods in more depth and Alexander alignment/awareness work to enhance vocal freedom and full body support of the voice. Areas include: breath support, vocal release, developing freedom in resonating areas, clarity in articulators, building range and stamina. Emphasis is placed on integration of methods with speaking of text. Writing projects are sometimes explored as a way to free the voice creatively and imaginatively. Voice/Alexander 1 is a pre-requisite to registering in this course.

Prerequisites: 54-305 and 54-106 and 54-105

54-307 Movement III

Fall: 5 units

This course is designed to provide students with an introduction to the actor training method of Tadashi Suzuki in conjunction with a more advanced investigation of the Viewpoints actor training gained in the student's first year. This course examines and explores the use of language and the human body as an expressive artistic instrument. Concepts of the body in relation to Time, Space, and Energy will be explored. This is a studio course in which learning is experiential.

Prerequisites: 54-208 and 54-207

54-308 Movement III

Spring: 5 units

This course is designed to expand the student's movement skills to include the basic principles and techniques of unarmed stage combat and an introduction to weapons fighting. As a studio course, activities will consist of learning and performing physical techniques, reading materials pertaining to the subject matter, viewing filmed examples of work, and giving performance presentations.

Prerequisites: 54-207 and 54-208

54-309 Dialects and Accents

Fall: 4 units

TBA

54-310 Dialects and Accents

Spring: 6 units

For School of Drama Acting/MT students only.

54-311 Rehearsal and Performance III

Fall: 16 units

Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom.

Prerequisites: 54-201 and 54-202

54-312 Rehearsal and Performance III

Spring: 16 units

Performance training through projects at different levels of difficulty and staging, directed by students and presented in the studio theatre. The actor has the opportunity to put into practice with his/her peers, in a creative and experimental atmosphere, the principles and techniques developed in the classroom. Note: Tues or Thurs time used as needed for performance critiques.

Prerequisites: 54-201 and 54-202

54-313 Dance III: Expand the Dynamics of Dance Technique

Fall: 3 units

Intermediate ballet. This course is dedicated to honing technical skills, expanding the classical dance vocabulary to the next level of difficulty, and addressing issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor

Prerequisites: 54-205 and 54-206

54-314 Dance III: Expand Dynamic of Dance Technique

Spring: 3 units

Intermediate ballet. This course continues to hone technical skills, expand the classical dance vocabulary to the next level of difficulty, and address issues of strength, stamina, and endurance. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-313 and Permission of instructor

Prerequisite: 54-313

54-315 Jazz III

Fall: 2 units

This course is to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor

Prerequisites: 54-217 and 54-218

54-316 Jazz III

Spring: 2 units

This course continues to expand the versatility of the student dancer to master more complex exercises, in dynamics, direction and rhythm using Jazz styles examined by decades. Understanding the 20th century historical background of the 20's, 30's 40's, 50's 60's and 70's. Course closed: Only for Music Theatre majors in Drama.

Prerequisite: 54-315

54-317 Singing for Actors III

Fall: 2 units

The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.

Prerequisites: 54-201 and 54-202

54-318 Singing for Actors III

Spring: 2 units

The students have a class voice experience which includes a physical and vocal warm-up and discussion and practice of healthy singing technique. There is group and individual rehearsal of potential audition and performance material. Toward the end of the term, there are weekly opportunities to perform in public, thus preparing for auditions.

Prerequisites: 54-202 and 54-201

54-319 Cabaret

Fall: 6 units

The Art of Cabaret: Explores the use of Stories and Song to communicate life experiences within an intimate setting, breaking down the invisible fourth wall for honest communication. The course includes a section on the use of the microphone for singers. This Study produces two Cabarets containing Material on a chosen Theme to provide hands-on Song Expression in a public forum.

Prerequisite: 54-220

54-320 Directing: for Digital Stages

Fall: 9 units

TBD

54-321 Acting III for Directors

Fall: 9 units

An examination of various directing styles with particular attention to: verse forms including Greek and Elizabethan, comedy/ farce texts and Early 20th century styles including Ibsen and Shaw. On occasion, guest directors for our main-stage productions will be engaged to teach the style of the production that they are presently working on. Alternately, there is the possibility of this semester being used for an applied internship with a major producing organization.

Prerequisites: 54-201 and 54-101

54-322 Directing III: INTRODUCTION TO TV & FILM DIRECTING

Fall: 9 units

An intensive introduction to directing with a camera in narrative film and episodic television for third year undergraduate directing and dramaturgy students. Students learn how to prepare for a camera shoot including breaking down a script, camera terminology, shot types and what can be accomplished, how to make a shot lists, visual style and how to express it. Students learn shot progression in the scene and point-of-view. This class will also include working with actors where we use a camera to film them under strict COVID guidelines.

Prerequisite: 54-222

54-323 Tap III - Expand Percussive Rhythms

Fall: 2 units

This course expands tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor

Prerequisites: 54-223 and 54-224

54-324 Tap III: Expand Percussive Rhythms

Spring: 2 units

This course continues to expand tap vocabulary and clear precision of execution through moderately difficult and extended combinations. Course closed: Only for Music Theatre majors in Drama. Prerequisite: 54-323 and Permission of instructor
Prerequisite: 54-323

54-325 Actor Dance III

Fall: 2 units

This course uses basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: Permission of instructor
Prerequisites: 54-202 and 54-201

54-326 Actor Dance III

Spring: 2 units

This course continues to use basic and fundamental contemporary Jazz styles, i.e. Latin, Blues, Lyric, African, to technically train the body using isolations and rhythmic patterns. Course closed: Only for Acting majors in Drama. Prerequisite: 54-325 and Permission of instructor
Prerequisites: 54-202 and 54-201

54-327 Auditioning for TV/Film

Fall: 2 units

An optional course for Junior Acting and Music Theatre majors.
Prerequisite: 54-202

54-328 Advanced Digital Sound Design Skills

Fall: 6 units

Sound Design Majors ONLY. Advanced sound creation and manipulation through student designed and constructed software and hardware.
Prerequisite: Conceptual Sound Design I.
Prerequisite: 54-267

54-329 Junior Theatrical Voice

Spring: 2 units

Missing Course Description - please contact the teaching department.

54-330 Introduction to Stage Management

Spring: 6 units

This course is intended to provide students an opening to the knowledge and skills of the professional stage manager. It will also illuminate the qualities of a good stage manager specific to personality and human interaction. Within this course we will examine the role of the stage manager throughout the full scope of creating a production, including preparatory work, rehearsal period, technical rehearsal, performance and closing.

54-331 Scenic Design: Explorations

Fall: 9 units

Students will spend the year in an exciting and intensive exploration of the process of Scene Design as well as an examination of the nature of creativity and storytelling. Students will also engage extensively in the skills a professional Scene Designer requires, such as drafting, drawing, model making, painting and general collaborative skills. Students will be expected to deal with in-depth research, scriptural examinations, careful arrangements of space, composition and groundplan, conceptual structure, real life obstacles and the elements of a successful final project. By the end of this course, students will have improved their overall design skills, have some projects they can include in their portfolio and have created new routes toward their creativity. (pre-req, intro to Scene Design)

54-332 Scenic Design: Boot Camp

Spring: 4.5 units

A rapid-fire design course for scenic design majors. This course offers the students the opportunity to work on six projects over the course of the semester. These projects may include contemporary, classical and non-linear plays, as well as TV workshop and a new plays collaboration with dramatic writing students. Co-taught by Scenic Design faculty.
Prerequisite: 54-250

54-333 Production Personnel Management

Fall: 6 units

Study of the management of production personnel for live theatrical productions. In depth analysis of union contracts from a management perspective: AEA, IATSE, USA. Projects in scheduling and budgeting based on those contracts. Study of hiring, evaluating, and retaining a quality staff. Examination of the role of safety protocols in production. The Course concentrates on the relationship between the Production Manager and all of the personnel that one comes in contact with. For Senior SMPM and TD ONLY or with instructor permission.

54-334 Production Resource Management

Spring: 6 units

This course examines the management of resources for the production of live theatrical productions. We start with analysis of scripts, to find the foundation for resource allocation. Then we move on to study the allocating two of the largest production resources: time and money. A significant exploration of the tracking of time and money extends throughout the course, with half of the class sessions taking place in a computer cluster, where we concentrate on advanced application of Excel, Access, and specialized calendar software.

54-335 Auditioning for the Stage

Spring: 2 units

An optional course for Junior Acting and Music Theatre majors.

54-336 Musical Theater History

Intermittent: 6 units

This course is a survey of musical comedy and musical theatre performances throughout history. Often considered a quintessential American theatrical form, we will also consider what "musical theatre" or "musical drama" means beyond the borders of the United States. The course will primarily focus in the time frame of 1860-present. We will examine the historical background, development and evolution of form, as well as impact and proliferation of this performance style. The course will involve lecture-based, discussion-based, and project-based styles of engagement. **No previous knowledge of or practice of "musical theatre" is necessary to succeed in this course. Open to non-majors.

54-337 Introduction to Lighting Technology

Fall: 6 units

Introduction to Entertainment Lighting Technology provides students with an overview of lighting equipment and software used in entertainment production. Topics include automated fixtures, console programming and pre-visualization software.

54-338 Theatre of the Oppressed-An Introduction to Forum Theatre Performance

Intermittent: 6 units

In what ways can theatre be used to solve social issues? This class will use theatrical storytelling to prototype solutions to unsolvable cultural problems. Using an applied theatre praxis, students will learn about the work of Augusto Boal's Theatre of the Oppressed, specifically Forum Theater as one way to use performance to address a specific social issue decided on by the students. As part of the course students will devise a performance for a live audience to engage with at the end of the class. Leading up to the final performance, students will learn, analyze, deconstruct, and think critically about how theatre can be used as a technique to engage in creating revolutionary change. As part of the course students will foster their facilitation skills leading games and debriefs for their peers. During this course it is possible that topics that are brought up will be personal in nature and potentially triggering. As such, students will also learn strategies for how to address their triggers when they become present. Students taking this course do not have to be familiar with the work of Augusto Boal nor do they need to have any prior performance experience. Open to non-majors.

54-339 Stage Management Seminar

Fall and Summer: 3 units

This class provides stage managers an opportunity to participate in in-depth discussion about the production process. Specific issues related to CMU productions and troubleshooting problems are a particular focus. The class also presents guest speakers on related topics and will work on longer-term projects as needed.

54-340 Coding & Control for Theatrical Sound

Fall: 5 units

This course will explore coding techniques, show control, networking and software applications within the context of theatrical sound design and amp; engineering. Pre-requisites 54267, 54166 and amp; 54389 (or permission of instructor).
Prerequisites: 54-389 and 54-267 and 54-166

54-341 Fundamentals of Costume Design

Fall: 9 units

Multiple studio projects comprise this one semester course that focuses on the principals and elements of design, including color theory, as they relate to Costume Design. Projects focus on the empowerment and development of each student's individual imagination. PRE-REQUISITE: Declared Costume Design Major in School of Drama. All others: Portfolio Review and special permission of teacher required. Drawing For The Theatrical Designer and Figure Drawing may be taken concurrently. FOR: First semester Graduate Costume Design and Costume Production Students, First semester Junior Costume Majors.

54-342 Costume Design for TV and Film

Spring: 7 units

A mini course in the second semester that explores the aesthetic and technical processes of designing costumes for the screen. The course introduces film-specific practical skills including the fundamentals of analyzing and breaking down screenplays for costume design, what design means during the pre-production and shooting phases of a production, and the aesthetic and technical differences of designing for the camera's eye compared to designing for the human eye. The course will consist of lectures, visual presentations, including viewing of films that illustrate the processes described in class, script break-down assignments, and design process projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Senior Costume Design students.

54-343 Lighting Design Skills 2

Fall: 3 units

TBA

Prerequisite: 54-367

54-346 Introduction to Costume Construction

Spring: 6 units

This sophomore level course is designed to provide an intermediate level of training in the area of clothing construction. Students will learn how to read patterns, prepare and cut fabric appropriately for construction purposes, and complete a garment employing necessary finishing techniques. Additionally, students will be exposed to the rudimentary skills necessary for basic flat patterning and begin the process of project time management and comprehension of product value.

54-347 Sound Workshops

Fall: 3 units

TBA

Prerequisite: 54-166

54-349 Automated Lighting Technology

Spring: 9 units

Automated lighting equipment is explored, with a concentration in programming techniques on advanced lighting control consoles.

Prerequisite: 54-369

54-350 Scenic Design Forum

Fall and Summer: 1 unit

Required weekly meeting of all Scenic Designers.

54-351 Theatrical Lighting Design

Fall: 9 units

The student's ability to analyze and translate information in the script to descriptive stage pictures is developed in a more in-depth process. Verbal, written and visual communication of ideas is emphasized and explored through texts and lab work. Issues of collaboration with the director and other members of the design team are discussed as part of the design process. Prerequisites: 54-252

Prerequisite: 54-252

54-352 Musical and Opera Lighting Design

Spring: 9 units

Through hands-on lab exercises and preparation of full lighting design plots, students will study lighting design for Musical Theater and Opera. The class will learn to visually analyze the emotional content of music, explore the various forms of musical performance, learn how to develop a design process, create focus in a large-scale space, and strategies for implementing a design.

Prerequisite: 54-351

54-353 Structural Design I

Fall: 9 units

Required for all senior undergraduate Technical Direction students. A concentrated training in Structural Design specifically developed for the theater technician. This course teaches the process of Allowable Stress Design for the engineering of scenic structures in wood and steel. Drama majors only, or with instructor permission.

54-354 Structural Design II

Spring: 9 units

Required for all senior undergraduate Technical Direction students. Upon completion of this two-semester sequence, students are familiar with beam and column design/specification, truss design, tensile systems and structural connections.

Prerequisite: 54-353

54-355 30 Hour OSHA

Intermittent: 2 units

For Production Technology and amp; Management majors.

54-356 Production Prep: Lighting Production

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama production and design students. The production experience provides students with experience in the following areas: production management, stage management, production run work, stage operations, design, lighting, sound, costume construction, prop construction, scenery construction, video and media, and scenic painting. Fully participating in these experiences will facilitate students' future success in the School of Drama as well as in the profession.

54-357 Directing: Production III JPP

Fall: 12 units

Assignments as stage manager or assistant director.

54-359 Introduction to Show Networking

Fall: 3 units

Introduction to Show Networking explores the integration of network structures and methods into entertainment production. Working from a textbook on the subject, the course will utilize a series of projects to demonstrate networking techniques as applicable in the field of production technology.

54-360 Leadership Workshop: Ethics & Innovation

Intermittent: 6 units

This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor.

Prerequisite: 54-333

54-361 Production Preparation

Fall and Spring

Participation in School of Drama productions in design or production roles.

54-362 Anti-Racist & Equitable Practices in Theater

Fall: 6 units

This course will be a series of workshops delivered in a hybrid format (partially online, partially in person, some independent work) exploring the topics of race and theatre with a primary focus on the US. Students will cover topics such as race and racism, creating welcoming theatre spaces, scene selections, tropes, and strategies for cultural competency and a survey of artists and theatres who have done culturally competent work. Practical skills around creating mission and values, cultural aesthetics, and advocacy will be covered. Students will practice research and critical analysis of various theatre systems as well as creative problem solving. Classes will not meet every week but the first day of classes August 30 and 31 will be in person where a schedule and syllabus will outline the semester.

54-363 Dramaturgy 4: Devising

All Semesters: 9 units

Dramaturgy students only. Others by permission. In this class, students will: - gain an introduction to the history and practice of devised and amp; documentary theatre - explore the dramaturg's role in devising theatre - investigate various methods for creating devised and amp; documentary theatre - learn techniques for developing theatre from source material - create original devised pieces in collaboration with other students

Prerequisites: 54-109 and 54-184

54-364 Dramaturgy 6: Showcase Prep

Intermittent: 9 units

For Dramaturgy majors.

Prerequisite: 54-363

54-365 Machine Design I

Spring: 9 units

Required for all senior undergraduate Technical Direction students. In this course, concepts from Physics of Stage Machinery are applied to the specification, selection, design and assembly of real-world mechanical components for the realization of winches, turntables, wagons and lifts for theatrical use. Drama majors only, or with instructor permission.

Prerequisite: 54-366

54-366 Physics of Stage Machinery

Fall: 9 units

This class teaches the basic physics of dynamic mechanical systems, specifically in the context of lifts, winches, turntables and wagons used in theatrical production. Material covered consists of Newtonian Dynamics, elementary mechanics, and fluid power. Required for all junior undergraduate PTM students. Drama majors only, or instructor permission.

54-367 Lighting Design Skills

Fall: 6 units

Students will concentrate on developing the skills necessary for lighting designers to successfully implement their designs in the theatre. Content includes communication, CAD programs, paperwork, focusing the show, programming conventional and moving light consoles, cue writing and expectations and responsibilities of the design assistant. Prerequisite: 54252
Corequisite: 54351
Prerequisite: 54-252

54-368 Introduction to Lighting Management

Spring: 6 units

Lighting Management I is an overview of the management process within a theatrical lighting department. Topics covered include communication tools, paperwork and physical resources used by department heads to facilitate lighting designs, as well as other duties performed within that role.
Prerequisite: 54-249

54-369 Lighting Management II

Spring: 4 units

Lighting Management II continues the investigation of the role of the department head within a theatrical lighting department, concentrating on skills needed to perform the role within the School of Drama.

54-370 Dramaturgical Sensibilities

Spring: 3 units

In this course, dramaturgy majors will meet with professionals in the field who have used a dramaturgical sensibility to build careers in "dramaturgy-adjacent" fields.

54-371 Production Preparation

Fall

Participation in School of Drama productions in design or production roles

54-372 Theatre for the Ear

Spring: 6 units

Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-166 Introduction To Sound Design, 54-267 Conceptual Sound Design 1 Restrictions: The course is open to sound design majors or with permission of the instructor.

54-373 Draping Fundamentals

Fall: 3 units

Draping Fundamentals is a half-semester introduction to the arena of the costume draper. This course illustrates what the draper's role is in effectively spearheading garment production for the performing arts, emphasizing the collaboration skills needed to propel a design from page to stage. The course instills a strong foundation in pattern development skills through the use of the dress or suit stand. Additional skills such as application of research, fitting procedures and protocol, pattern manipulations and refinements and complete construction plans are explored. This class provides tangential learning through a thorough investigation of sculptural and spatial relationships, emphasis on strategic planning, development of fine motor skills, and exposure to a broad spectrum of materials and methods that can be adapted to other purposes.

54-374 Musical Theater Audition

Spring: 5 units

Missing Course Description - please contact the teaching department.

54-375 IDEATe: Robotics for Creative Practice

Fall: 9 units

Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include programmed motion control, pneumatic machine design, closed-loop feedback systems, machine choreography, and human-robot interaction. Discussion topics include contemporary kinetic sculpture and animatronics. This interdisciplinary course is part of IDEATe Physical Computing but is open to any student.
Prerequisites: 15-104 or 15-110 or 60-210 or 99-361 or 60-212 or 15-112

54-376 Entertainment Rigging

Spring: 3 units

This course is a survey of the techniques and practices of theatrical rigging. The course has two main components: permanently installed rigging systems typically found in theatres, and background and technical information concerning the components typically used for stage rigging. Discussion topics include selection criteria for line, hardware, and terminations stressing entertainment industry standards, workplace safety and common industry misconceptions. Time permitting the course will shift from a general discussion of components to their assembly into custom rigging systems and amp; solutions. Instructor's permission only.

54-377 Production Composition Studio

All Semesters: 3 units

This course is a laboratory style studio class. It is designed to support the student through the process of composing music for theatrical and amp; film productions and projects. Students will be required to bring ongoing creative work materials to class.
Prerequisites: 54-389 and 54-390

54-378 Technical Direction II

Spring: 6 units

This course is an exploration of techniques and practices of Technical Designers. The class has four main components: an exploration of the types of strategies used by Technical Designers to arrive at solutions, building an expert vocabulary for discussion of technical design issues, development of actual technical solutions, on paper, in discussion, and in the shop, discussion of any pertinent technical issues for any of the school productions while in development.
Prerequisite: 54-273

54-379 Captured Storytelling

Fall: 7 units

In this course we will consider the differences between traditional live storytelling and stories that are captured to be viewed remotely or at a later date. Using the lens as the proscenium, you control how your audience experiences the story. How do you prepare for that? How does the lens change the way we design? We will talk with and explore the work of industry professionals such as directors, cinematographers, production designers, editors, and costume designers. Hands on, we will storyboard and shoot our own stories.

54-380 Music Reading for Production

Fall: 3 units

This class gives the basics of music theory, musical terminology and score reading. Students focus on the difference in various musical scores, ie. piano/vocal, full, hand written scores. Students are guided in classroom listening which a wide variety of music including, opera, musical theatre, ballet, and choral/orchestra works.

54-381 Special Topics in Drama: History, Literature and Criticism

Fall and Spring: 6 units

Every semester, members of the School of Drama's faculty offer seminars on special topics that investigate some aspect of theatre history, dramatic literature, dramatic theory, or a particular author, period, or genre. ___

Section A-Contemporary Comedy by Historically Underrepresented Groups:

In this course, students will read and analyze comedic plays of the late 20th and 21st centuries, focusing on plays by women and members of the LGBTQIA+ community through discussions, responses, and in-class activities. Together, we will examine the genre of comedic playwriting through the lenses of race, sexuality, gender, and the intersections between them. Students will investigate the narrative form of comedy as well as its relevance to theatre and contemporary issues. Playwrights we will study may include: MJ Kaufman, Lynn Nottage, Sarah Ruhl, SMJ, Young Jean Lee, Danai Gurira, Yasmina Reza, and more. ___ Section B- This course will examine non-Aristotelian approaches to performance work from the last century. Together we will look at the work of artists whose work has pushed the boundaries of our theatrical expectations. Starting with the work of Bertolt Brecht and the epic theatre we will work our way towards the present moment. We will look at how the work of early 20th century theatre artists have influenced work under the umbrella term "Contemporary Performance". This course will highlight how non-Aristotelian theatrical structures, for the last century, have been used by artists from underrepresented communities and the global majority to tell their stories. Artists studied in this course may include, but are not limited to; Brecht, Lorca, the Living Theatre, Liz Lecompte, Amiri Baraka, Fake Friends, Young Jean Lee, Ntozake Shange, Taylor Mac, Sarah Kane, Chuck Mee, Suzan Lori-Parks, Celine Song, 600 Highwaymen, Elevator Repair Service.

54-382 Anti-Racist Theater: In Context

Fall: 4.5 units

TBD

54-383 Introduction to Digital Media

Fall: 9 units

Software Covered: AutoCAD, Photoshop, Illustrator, InDesign, Sketchup, Vray for Sketchup Concepts Covered: 2D Graphics, Architectural Drafting, 3D Modeling and amp; Rendering, Hybrid Representation Limited to Drama students: Scenic Design Juniors, 1st Year Graduate Students

54-385 Automated Lighting Rig Engineering

Spring: 6 units

Students continue to develop technical drawing and engineering skills while completing the decision-making process for the implementation of a concert lighting rig.

54-386 Scenic Design Skills: 3D Model Making

Spring: 4 units

In this mini students explore a variety of three-dimensional media techniques as they learn to build models for the Scenic Designer. Students will investigate many aspects of model-making, from basic structural ideas to complex organic and architectural forms, furniture, and advanced techniques such as scale painting, soldering and carving. Through these methods, students will develop a better understanding of space and objects in space in the theatre.

Prerequisite: 54-231

54-387 Dramaturgy : Production I

Fall and Spring: 9 units

Working as a production dramaturg for a Horizons Reading or as an assistant dramaturg.

54-389 Composition for Theatrical Sound Design 1

Fall: 9 units

Composition for Theatrical Sound Design 1 This course will concentrate on developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. The rst semester will examine the building blocks of composition such as rhythm, modes, harmony and counterpoint. The second semester will focus on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester you will practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-390 Composition for Theatrical Sound Design 2

Spring: 9 units

This course will concentrate on further developing compositional skills for use in theatrical sound design. The full length of this course is designed to take place over two semesters. This is the second semester and builds on compositional techniques such as writing melody, harmony, counterpoint and orchestration techniques. The second semester focuses particularly on more advanced skills in composition within a theatrical context. Through projects distributed throughout the semester students practice the skill-based techniques of music notation, orchestration, synthesis, sequencing, working with instrumentalists and the creation and utilization of sample-based instruments. This course will also cover textual analysis as it applies to both the inspiration for composition and to the more direct challenge of setting music to text.

54-391 Lighting Design for Directors

Fall: 4 units

An exploration of the lighting design process that will provide the tools for stage directors to communicate, collaborate and explore with designers. Students will explore the physical properties of light and the artistic potential of light through script analysis and hands on use of the Light Lab. (For Junior Directing Students)

54-392 Scenic Design Skills: 2D Drawing and Rendering

Spring: 4 units

This mini offers practice in two-dimensional drawing and rendering for the theatre.

54-394 Production Prep: Put Your House in Order

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-396 Theatrical Lighting Management

Fall and Spring: 6 units

Theatrical Lighting Management continues the investigation of the role of the department head within a theatrical lighting department, concentrating on skills needed to perform the role within the School of Drama.

Prerequisite: 54-368

54-397 Sound Design For Interactive Environments

Spring: 9 units

This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current and amp; emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.

Prerequisites: 54-267 or 54-268

54-398 Special Topics in Sound Design

Spring: 9 units

A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio. Prerequisites: 54-166 Introduction To Sound Design for Theater, 54-267 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.

Prerequisites: 54-166 and 54-267

54-399 Decoding Media

Fall: 9 units

Media technologies are designed to do a lot with very little effort. This creates a problem of abundance for artists trying to use these technologies in creative ways. One can relatively quickly pull images off the internet and project them huge onstage, but what does it mean? Decoding is the term I'm using to help you keep control of your process and create meaningful (not just dazzling) imagery for the stage. The entire theatrical process can be considered as a series of decodings and re-encodings, first decoding the text/idea (by the creative team), re-encoding (the design) and finally decoding by the audience. This class is designed to give students a solid foundation in contemporary media design skills while simultaneously providing an examination of the function of theater historically and the ways media technologies fill those needs today. Early assignments focus on students use of media in their everyday lives, by keeping media journals and bringing in media objects for examination. Later classes focus on taking ideas from this research and applying them in conceptual stage designs for an ancient Greek play and then a controversial adaptation from the 1990's by Sara Kane. Students learn how to go from textual analysis to a visual interpretation and staging with media. The class takes students through the process of initial creative brainstorming, to communication tools (concept sketches, digital renderings, 3D models), onto specifying a design through CAD documentation, projection optics calculations and final design presentations.

54-400 Staging Media

Spring: 9 units

Staging Media is a practical, process-oriented class, focused on building the skills to go from a conceptual design to an actual completed show. We cover how to create, rehearse with and stage meaningful media designs. Through real-world examples, students will learn the best practices for bringing their designs to life. Students are expected to master a wide range of material. Required for new VMD Juniors, 1st Year VMD Grads; others by permission.

54-401 Through the Lens : Storytelling with the Camera

Fall: 9 units

A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions.

54-402 Through the Lens : Storytelling with the Camera

Spring: 9 units

A unified, cross-disciplinary class focused on the artistic and technical requirements for single-camera storytelling. Students from each discipline will receive theoretical instruction, progress to in-class practicum work, and become an integrated production team on a field film project experience. The idea embraces: a single weekly time-frame for classes across several disciplines, a reintegration of management students; and a retooled Camera Lab class in which actors, writers, designers, managers and directors collaborate. Professional guest artists will be frequent visitors to the classroom and production process. Classes will include topics of universal interest to the larger group as well as discipline specific sessions. Prerequisite: 54-401

54-403 Advanced Speech Techniques

Fall: 3 units

TBD

54-404 Writer's Room Workshop

Fall: 9 units

TBD

54-405 Digital Narratives

Fall: 5 units

This course combines options from the School of Drama in a unique configuration: through working collaboratively across disciplines, students will investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through exercises, readings, and viewing of other artist's work. This Fall the course will explore the wide variety of digitally mediated forms for online, remote and distanced work - techniques of collaboration, creation and experiencing of performance focused work. We will pursue multiple techniques for cross-platform storytelling, drawing from students' lived experiences to engage the current political and social milieu via multiple digital and mediated systems. Experimental and devised processes of theater making have long mined the complex relationship between the form and the content of an artwork - how can we do so in pursuit of a critical/political perspective? Students will become familiar with contemporary and historical companies who work this way and through small group in-class workshops create new narrative experiences and share them with the larger class. Through embracing these tools and forms, we utilize the theatrical conversation to engage in artistic discourse to discover new complexities of meaning. We invite students to come explore these possibilities in a spirit of experimentation and group exploration.

54-406 Media Creation Studio I

Fall: 6 units

Missing Course Description - please contact the teaching department.

54-407 Movement IV

Fall: 6 units

Movement IV is a Lecoq-based course that focuses upon the creation of actor generated physical theatre. In contrast to the actor-as-interpreter tradition, class work is completely centered upon the actor-as-creator. All performance material is created by the students themselves. Class work includes solo, duo, and ensemble explorations. Improvisational prompts and various themes will be introduced and explored, resulting in improvised or semi-rehearsed presentations. Potential themes include autobiographical material, topical issues, original music theatre, inspirations from nature, interpretations of art (music/poetry/paintings), mask performance, contrasting characters, clown entrees, etc. A final project or projects will be determined by the class material generated throughout the semester, as well as by student interest. Limited to Acting/MT majors only. Prerequisite Knowledge: Movement I, II, and III Prerequisites: 54-207 and 54-208

54-408 Drama Directing TBA

Spring: 6 units

TBA

54-409 Theatre Lab for Undergraduates I

Fall

This is a two-semester class which teaches the collaborative process of theatre and #8212; including the role of the living dramatic writer. New scripts are written by graduate dramatic writers, then developed and realized by junior actors, senior dramaturgs graduate and undergraduate directors with the playwright. This work results in 10-minute play scripts, one acts, monologue dramas, and the texts for the MFA Thesis Productions. This class is co-taught by the Acting Dramatic Writing, Dramaturgy and Directing Options.

54-410 Theatre Lab for Undergraduates II

Spring

Theatre Lab is a place to practice collaboration. We will examine and explore the relationships between actor, director, and playwright in working on new plays. The objectives are to prepare students to work collaboratively on new play production as it is practiced in the field, to understand the responsibilities of actor, director, and playwright in work on a new text, and to practice being an outstanding collaborator.

54-411 Rehearsal and Performance IV

Fall: 16 units

Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.

Prerequisites: 54-311 and 54-312

54-412 Rehearsal and Performance IV

Spring

Participation outside of class requirements in departmental productions. Putting into practice the techniques acquired over the years of training and exploring the development of a performance played before the public over two weeks.

Prerequisites: 54-311 and 54-312

54-413 Showcase

Fall: 6 units

Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.

Prerequisites: 54-301 and 54-302

54-414 Showcase

Spring: 9 units

Senior acting class for actors and Mt's who are in good standing and in position to graduate in the Spring. Preparation for the New York and Los Angeles Showcase presentations.

Prerequisites: 54-301 and 54-302

54-415 Broadway Dance Styles

Fall: 5 units

This course is designed to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama. Prerequisite: Permission of instructor

Prerequisite: 54-319

54-416 Broadway Styles

Spring: 5 units

This course continues to provide the student with a practical and historical knowledge of the dance repertoire in American Musical Theater using the original choreography from prominent Broadway choreographers. Course closed: Only for Music Theatre majors in Drama.

Prerequisite: 54-319

54-418 Songs for Showcase

Spring: 2 units

Vocal preparation for Senior Showcase presentation.

Prerequisite: 54-500

54-419 Production Prep: TBA 11

Fall and Summer

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-420 Production Prep: Ottone in Villa

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-421 Production Prep: A Doll's House

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-422 Directing IV: Next Steps

Spring: 9 units

TBD

54-423 Production Prep: Schauspieldirektor/Telephone

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-424 Production Prep: Passage

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-425 Production Prep: Want to be a Mother

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-426 Production Prep: Lear

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-428 Production Prep: Macbeth

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-429 Production Prep: TBA 10

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-430 Production Prep: TBA 9

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-431 Scenography

Fall: 9 units

A core design class between scenic designers, costume designers, media designers, and directors collaborating to create projects on paper. This class allows students to experiment away from the pressure of a realized production. The course encourages students to cross traditional boundaries in their own work and to focus on the idea of world building for their projects. This class often includes guest designers and directors.

54-432 Scenic Design: Design for Spaces

Spring: 4.5 units

A3: Design for Live Spaces: Scenic Design is a course that focuses on creating design within the format of live performance. The projects will be varied and will include new works, existing texts and other innovative forms of live design within the community. A4: Design for Screen Spaces: Scenic Design is a course that focuses on design for the screen. The projects may alternate between TV and Film design depending on the year. Industry professionals will be part of the course experience, giving students real-time knowledge. Projects will build towards a portfolio of work for use in the industry. This course focuses on developing the design tools in areas such as: research, collage assembly, model making, storyboards and creation of a short reel amongst other things.

54-433 The Basics of Self-Producing for Theater Artists

Fall and Spring: 6 units

Is self-producing for you, or do you prefer to use other people's resources? Basics of Producing for Theater Artists will introduce the mechanics of getting your work to the spectator while creating a sustainable life as an artist. We'll investigate old models and new platforms to help you find the location and the recipe for your unique mission. We will walk through budgeting, fundraising, marketing, contracts, rights, risks, and the audience of the future. As a final project, you will assemble a package you can hand to a potential funder that explains why your theater is needed to fill a void in the culture, and why no one is better suited to do it.

54-434 Production Prep: TBA 3

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-435 Production Prep: External Projects

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-436 MT Senior Voice Coaching

Spring: 1 unit

No course description provided.

Prerequisite: 54-500

54-437 Acting IV

Spring: 6 units

Tbd

Prerequisites: 54-301 and 54-302

54-438 Acting IV-Improv

Spring: 3 units

Introduces students to Comedy Improv performance; gives students an improv vocabulary; increases students freedom on stage; stimulates students sense of play; and increases students awareness of rhythm/timing/build/fall/recovery.

Prerequisites: 54-302 and 54-301

54-440 Production Prep:TBD 12

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-441 Costume Design for Dance

Fall: 5 units

A mini exploring the design elements specific to the aesthetic and performance requirements of dance. The course will examine the design of costumes at significant points in the history and evolution of dance, from classical ballet to a wide range of modern genres. Coursework will consist of lectures, visual presentations, viewing of filmed footage of notable dance performances, and research and design projects. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: Second year Graduate Costume Design majors and Junior Costume Design students.

54-442 Costume Design for the Classics

Spring: 5 units

This course focuses on left and right brain approaches to complex classics written by a playwright chosen from amongst Moliere, Brecht, Pedro Calder and #243;n de la Barca, and Shakespeare, as well as contemporary female playwrights such as Sarah Ruhl, Ellen McLaughlin and Lauren Gunderson who have written plays inspired by the classics. Special attention is paid to process: research, critical thinking, character development, style, nuts and bolts paperwork, and the honing of each individual designer's skills. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Junior Costume Design students. Prerequisite: 54-341

54-443 Production Prep: Looking at You

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-444 Advanced Designer Draping

Spring: 6 units

Advanced Designer Draping is a continuation and development of the proficiencies established in Draping for the Designer I. This course emphasizes the draper's role in the creation of period women's wear: its history, unique pattern challenges, specific construction techniques, and how to manage its creation in the workroom. The synthesis of historical understanding with requirements for the performing arts is underscored. Through the patterning, fitting and making of a multi-layer, historic costume each student undertakes interrelated projects that allow for the application of research, development of complex patterns, composition of complete construction plans and fostering of effective teamwork. To take this class, the student needs to have taken either 54-373 Draping for the Designer I or 54-814 Draping for the Graduate Designer I or to have a background in draping and gain permission from the instructor.

Prerequisite: 54-373

54-445 Commercial Intensive

Fall: 3 units

This course helps actors to develop an understanding of commercial type, work with commercial copy, learn about the SAG-AFTRA commercial contract and use wardrobe, technology and self-taping to best effect in order to book commercial work.

54-446 Professional Prep for Costume Designers

Spring: 3 units

An optional professional preparation course geared toward Costume Designers entering the theatre industry. The slide/lecture course will cover doing taxes, job search information: including resume formatting, cover letter styles and tone, portfolios and websites; United Scenic Artists' union membership and benefits, "How to Survive the First Years in the Business." Minimal homework.

54-447 Figure Drawing

Fall: 3 units

Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-449 Production Prep: Carnegie Scenic

Fall and Spring

tbd

54-450 Painting for the Theatrical Designer

Intermittent: 9 units

This studio course focuses on watercolor and acrylic techniques applicable to subjects relative to scenery and costume design. The human figure, architecture, landscape, furniture, clothing, accessories, fabrics, props and building materials for both scenery and costumes are explored. Rigorous practice required. PRE-REQUISITE: Drawing for the Theatrical Designer. All others: Portfolio Review and special permission of teacher required. FOR: All Design/PTM majors- specifically scene and costume design students
Prerequisite: 54-473

54-451 Drama - TBD

Fall: 6 units

TBD

54-452 Architectural Lighting Design

Spring: 9 units

The study of Architectural Lighting Design for interior and exterior spaces.

Prerequisite: 54-252

54-453 Production Management Workshop

Fall and Spring: 3 units

Investigates the organization, planning and interpersonal skills required to successfully manage a live theatrical production. Course is discussion based on 1) participants experience in laboratory productions in the School of Drama, 2) current practical examples of experiences of professional production managers, and 3) contemporary management texts. Topics covered include: Budgeting, Scheduling, Communication, and Project Management. Permission of instructor required.

54-454 Advanced SM: Management Styles

Fall and Spring: 6 units

In-depth exploration of Management Styles, examination of personal approaches, collaboration, and priorities for the future

54-455 Production Data Manipulation

Spring: 9 units

In depth analysis of how to work with production data across multiple software platforms to allow the Production Manager to make more informed decisions. Required for Production Management / Stage Management majors.

54-456 Production Preparation

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. In the Lighting Production course students will work within technical lighting teams to support production work on School of Drama shows and events.

54-457 Directing: Production IV

Fall

SENIOR DIRECTING CAPSTONE: Fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for an audience; to tell an entire theatrical story with a beginning, progression and ending; to extend practical understanding of Theatre as a collaborative process; to synthesize and apply prior studies at Carnegie Mellon, or other approved Capstone Project.

54-458 Directing: Production IV

Spring

SENIOR DIRECTING PROJECT: This is a 90-minute, public, fully-designed presentation directed by a 4th-Year Directing student with the following goals: to publicly realize a playwright's purpose for a live audience; to tell an entire theatrical story with a beginning, progression and ending; to work as a team with actors and design team to shape a cohesive and amp; coherent theatrical presentation; to extend practical understanding of Theatre as a collaborative process; to synthesize and apply prior studies at Carnegie Mellon.

54-459 Future Stages for Undergrad Directors and Dramaturgs

6 units

FUTURE STAGES is a graduate level course (Drama undergraduates by permission only) which combines options from the School of Drama in a new configuration: through working collaboratively across disciplines, students investigate multimedia approaches to contemporary theater and new ways of storytelling. Directors, designers, actors, and dramaturgs work in groups to generate original ideas, images, texts, and material in a workshop environment. These working groups create projects over the course of the semester which are shown in informal presentations. The emphasis is on process, not product and #8212; devising an interdisciplinary performance requires a keen focus on combining creative invention with a rigorous structure of concept development and #8212; both of which are explored here. We also examine the work of several significant contemporary theater artists whose work approaches collaboration across a variety of disciplines. Artists have included: Ariane Mnouchkine, Dumbtype, Complicite, Ralph Lemon, Robert LePage, and more. Students learn to define and distinguish these artist's approaches through viewing video excerpts, readings, and discussion. This class is an opportunity to explore avenues outside of traditional production modes and beyond each student's individual discipline. We focus on the process of creating a theatrical language which truly integrates disciplines.

Prerequisite: 54-222

54-461 Experimental Capture

Fall and Spring: 12 units

TBD

54-463 Production Prep: TBA 2

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-464 PTM Professional Practice

Spring: 3 units

A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-465 Production Prep: TBA 1

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-466 Advanced Entertainment Lighting Programming Lab

Spring

Students will explore advanced techniques and methods while programming on top-end lighting control systems.

54-467 Costume Design with Music

Spring: 5 units

A second semester exploration of costume design for musicals and opera that engages students in aesthetic and practical techniques applied toward these two genres. Extensive presentations of the history of opera and musicals comprise most of this class. Students choose the opera or musical they wish to design. Special attention paid to music skills, glossary, process, research, designing for principals and chorus, swatching, nuts and bolts paperwork and the honing of each designer's individual skills. PRE-REQUISITE: Design/PTM Costume major. All others: Portfolio Review and special permission of teacher required. FOR: First year Graduate Costume Design majors and Senior Costume Design students.

54-468 Theater Management

Intermittent: 6 units

The course examines theatre enterprises, focusing on both existing and emerging business models for producing or presenting theatre organizations from Broadway to Omaha. Theatres are uniquely responsive to their audiences and ecosystems, hence, the course will investigate how the business works - internally and externally. While programming (plays) are at the core of the theatrical exchange, this course will focus its attention on the institutional frameworks that provide the financing, staffing and audiences to those works. The course will be organized in a seminar structure. Lecture will occur to deliver core concepts but the course emphasizes discussion, individualized investigations and creative projects.

54-469 Dance Lighting Design 1

Fall: 3 units

Through hands-on exploration, lecture and discussion, students will develop a design process for lighting dance. Topics will include: historical background of dance roots, approaches to lighting ballet and modern dance, designing a dance rep plot, and dance lighting techniques.

54-470 Costume Rendering

Spring: 9 units

This fast-paced course focuses on techniques and exercises specific to the development of versatile costume renderings enhanced by the mediums used in the creation. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of a range of techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to the development of designs for production and portfolio preparation. PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. Prerequisite: 54-473 Prerequisite: 54-473

54-473 Drawing for Theatrical Designers

Fall: 9 units

This semester-long basic drawing course focuses on developing hand-eye coordination through discreet studio exercises that allow the theatre student multiple entry points into drawing. Developed for theatrical design students, accurate drawing of proportion while viewing first hand subjects and research images is stressed. Marker and pencil use only. Rigorous practice required. PRE-REQUISITE: Design/PTM major. All others: Portfolio Review and special permission of teacher required. FOR: First semester Graduate Design and Production Students, First semester Junior Costume Majors, other Design/PTM students by consent of instructor.

54-475 Advanced Topics in SM: Cross-Cultural & Interdisciplinary Collaboration

Fall and Spring: 6 units

This class will use the theory of cultural intelligence to explore cross-cultural and interdisciplinary collaboration in the world of performing arts and entertainment. We will delve into different interdisciplinary artists and productions' unique culture and process on both national and international platforms. The learning intention is to develop the students' managerial culture awareness and adaptability when encountering different areas including dance, branded experiences, theme park, cruise line, award shows, concerts, and USO Entertainment (United Service Organizations).

54-476 Media Creation Studio

Fall: 6 units

This class will strengthen the student's video content creation process while centering conceptual strength in video design for live applications. Skills taught will focus on workflows and best practices for creating media content for live performance context. Tools and skills taught include FFmpeg transcoding, video generation via TouchDesigner, Advanced Millumin and NDI workflows. This intensive workshop style class's corequisite is the course Expanded Theater. This pairing will allow students to apply the skills acquired in this class to multiple collaborative and live mediated projects. Class time will be reserved for technical lectures/demonstrations. The majority of work associated with project assignments will take place in the corequisite Expanded Theater.

54-477 Technical Direction III

Fall: 6 units

Required for all senior undergraduate Technical Direction students. This "capstone" course is the second semester of a sequence requiring application of concepts from earlier courses including Standard Scenery Construction, Production Planning, Structural Design, Stage Machinery Design and Technical Design 1. This is a project-based course requiring weekly presentation of solutions to various "unusual" technical challenges, drawn from actual production experiences. Thorough documentation (shop drawings, budgets, build schedules, etc.) is a requirement for each project. Prerequisite: 54-378

54-478 Lighting for the Camera

Fall: 3 units

Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each team's script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work. Prerequisite: 54-469

54-479 Lighting for the Camera 2

Intermittent: 3 units

Through hands-on exploration in a studio setting, students will learn the basics of how to light for camera. A professional television lighting designer will mentor the students through the design process in a three-day workshop. Student teams will be formed comprised of a director, writer, lighting designer, costume designer, art director and actors. Each team's script will be produced in the Wells Video Studio as a three-camera shoot. Following the completion of taping each scene, students will view the final results and receive feedback on their work. Prerequisite: 54-252

54-480 Technical Direction IV

Spring: 6 units

The purpose of this class is to prepare Technical Directors as Technical Designers, specifying the engineering and fabrication of discrete scenic elements in a production context. Upon completion of this course, students should be able to: Understand how elements function to support production Recognize the limitations of standard approaches Develop unique approaches to technical challenges where appropriate Work with an ever-expanding body of methods, materials and hardware Integrate knowledge from prior PTM coursework Develop effective drawings and prototypes Iterate technical designs to achieve optimization Prerequisite: 54-477

54-486 Understanding Textiles

Spring: 3 units

Understanding Textiles is a half-semester introduction to the textiles used for the performing arts. This course begins with an overview of the historical development of textile technology and the role cloth plays in world economies. Next it examines weaving structures and how they impact suitability for particular applications. Techniques for identifying fibers, weaves and fabric density are learned. The course culminates with a project that uses all the explored skills, a fabric in history swatch book. Each student takes an era of history, researches cloth production at that time, finds period appropriate swatches, accurately identifies them and suggests uses for each. These individual chapters are combined into a large resource book, a copy of which each participant keeps for future reference.

54-487 Dramaturgy: Production II

Fall and Spring: 12 units

Working as a production dramaturg for a School of Drama production in the junior year.

54-488 Dramaturgy: Production II

Spring

Working as a production dramaturg for a season show or a professionally-produced show at a LORT or similarly-ranked theatre in the US or abroad, in senior year.

54-489 Dramaturgy: Internship

Fall and Spring: 9 units

Professional internship with a dramaturg at a LORT or similarly-ranked theatre in the US or abroad.

54-490 Special Topics in Media: Mediated Reality

Spring: 10 units

Mediated Realities is an advanced studio course that investigates the potential applications of mediated-reality technologies and location-based interactivity for storytelling, site-specific art-making, and live performance (broadly defined). Converging trends in cultural production, mobile computation, and media technologies present new affordances for artists and designers to shape location-based experiences. Studio work engages a breadth of strategies in post-media aesthetics, as related to one's experience and understanding of place. Trans-media storytelling, real-time graphics, machine learning, gamification, locative artworks, augmented reality and powerful portable media devices present opportunities for artists and designers to create experiences that heighten multisensory experience by merging live performance and participant interaction with systems for digital information, imagery, and 3D visualization - all ubiquitously available in low-cost and widely distributable formats (e.g. apps, mobile web sites). The course frames technological experimentation in the context of 1970's Land Art, Happenings, Fluxus games, Performance Art, Expanded Cinema, and the unresolved theoretical issues emerging from this rich period in American history - site specificity, competing definitions of "community," the effects of media and representation, audience/performer dynamics, and the nature and limits of the art work. Reading discussions, site visits, and presentations from outside experts (CMU faculty, visiting artists) will expose a range of relevant topics, disciplinary and creative perspectives, and potential avenues for investigation. Specific areas of focus will include Pittsburgh history, local ecological dynamics, labor history and the effects of technology on the landscape and lives of Pittsburgh's population.

54-491 Concert Lighting Design

Fall: 9 units

Students will explore lighting design for concert touring. Emphasis will be on the conceptual development, design process, music analysis, methods of rendering ideas and strategies for implementation of designs. The course will demonstrate methods of working with the tools, vocabulary and technology available to the concert lighting designer.

54-493 Business of Acting & The Practice

Fall: 4 units

This course introduces the (advanced) actor to various aspects of the professional world. Emphasis is placed on the audition and interview process for casting directors, talent agents and personal managers. Each student will present either an individual or small group project chosen from a wide ranging list of topics which include performers unions, various production contracts, New York and regional theater seasons, professional publications and web sites. Occasional tests are administered on the subject of current Broadway and Off-Broadway seasons. Registration for this course is limited to Drama majors only.

Prerequisites: 54-301 and 54-302

54-497 Directed Study

Fall and Spring

An opportunity to pursue a predefined design project outside of the standard curriculum under the guidance and direction of a School of Drama faculty member. By special permission only.

54-498 Expanded Theater

Intermittent: 9 units

Expanded Theater is a hands-on studio course where students work with a wide variety of media, network, and computational technologies in a performance-focused workshop environment. Students work in small teams, experimenting and iterating, with low-stakes showings, to gather feedback and see things "on their feet." Through working collaboratively across disciplines, students investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through these exercises, readings, and viewing of other artist's work. The course is open to all students who are excited by "thinking with media" and how the systems and technologies we use every day can be incorporated more deeply into the design, dramaturgy, and experience of contemporary performance. The course will take place off-campus at the Melwood Building, and students will have a variety of different spaces to explore the creation of these hybrid media/performance experiences. The CMU Shuttle will allow students to quickly get to and from campus. Considering theater as an ancient technology of mass participation and social cohesion, this course explores how emerging technologies can expand upon the basic theatrical relationships in new and culturally relevant ways. Collaboration and integration of design, media, and storytelling is critical to this approach. The Melwood Building is the former Pittsburgh Filmmakers building that is being re-imagined as a performance and technology research center, engaging many schools and outside partners who are exploring how new technologies, networked systems, and experimental artistic practices bridge previously separate disciplines and open-up new possibilities for storytelling, performance, and art. This course is a model for this new collaborative initiative between Drama, Art, and other CMU Schools.

54-499 Advanced Digital Image

Intermittent: 6 units

Advanced Digital Image: (Mini) This class is designed to teach students how to conceive, create and present large scale, professional-quality imagery at "realistic" budget levels. Students choose specific theatrical scenes and create a media based solution for them. Through in-class workshops and Media Lab work-time, this class covers High Definition video production, editing, animation and amp; live video systems for the stage as well as a variety of media-server based presentation technologies. For Juniors, Seniors and Grads. No Prerequisite Open to non-majors

54-500 Voice Lab

Fall and Spring: 5 units

FOR MUSIC THEATRE MAJORS ONLY. Singing Voice based on speech-level and classical singing techniques, required of all Musical Theatre Majors. Lessons are private, for the duration of one hour per week. Voice Lab combines all students of Musical Theatre in a one-hour performance class, where repertoire is performed for faculty and students alike. Training is progressive, with each semester building on the vocal mastery achieved from the previous semester. Repertoire spans from classical to rock, but with an emphasis on songs extracted from the American Musical Canon.

54-503 Directors' Practicum

All Semesters: 2 units

A mini-semester course introducing career paths and professional tools for directors.

54-505 Ear Training

Fall: 1 unit

Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-508 Theatrical Sound System Design 1

Fall: 9 units

Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions.

54-509 Theatrical Sound System Design 2

Fall: 9 units

Intensive course exploring the theory, art and technology of large scale sound system design for entertainment, specifically live theater productions. Prerequisites: Intro to Sound Design for Theatre and Production Audio, OR permission of instructor.

Prerequisites: 54-166 and 54-666

54-511 Millinery I

Fall: 9 units

This course surveys basic hat making skills and allows students to create project work in the areas of simple construction, blocked felt and buckram shapes.

54-513 Millinery II

Spring: 9 units

Millinery II (513/914): This course continues the explorations begun in Millinery I. The student undergoes advanced exercises in straw, wire frames, block making and non-traditional millinery materials. Continued emphasis is given to developing professional level skills and assimilation of advanced theories.

Prerequisite: 54-511

54-516 Fabric Painting

Spring: 9 units

This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester.

54-517 Directors Common Hour

Fall: 1 unit

Directors Colloquium is a weekly meeting for undergraduate Directing majors and BXA students in directing. Specific topics in directing are discussed and School of Drama productions are critiqued.

54-518 Director's Colloquium

Spring: 1 unit

Missing Course Description - please contact the teaching department.

54-519 Acting for the Camera

Fall: 6 units

This course teaches the skills necessary to work as an actor in the film and television industry. Incorporating the proficiencies and techniques acquired during previous training, we'll learn and practice the additional skills required to work on camera.

Prerequisite: 54-302

54-520 Acting for the Camera

Fall and Spring: 8 units

This course teaches the skills necessary to work as an actor in the film and television industry. Incorporating the proficiencies and techniques acquired during previous training, we'll learn and practice the additional skills required to work on camera.

Prerequisite: 54-302

54-521 Video Media Design Senior Thesis

Spring

TBA

54-522 Director/Dramaturg Play Lab

Spring: 3 units

Run by and for the directors and dramaturgs of the sophomore class, this course will foster collaboration while reading new plays every week. With a focus on analysis, presentation, and pre-production skills, the goal is to bring together directors and dramaturgs, while preparing for BFA Directors' Senior Capstone project

54-524 Dance Lighting Design 2

Fall: 3 units

TBA

Prerequisite: 54-469

54-525 Entertainment Lighting Programming

Fall: 9 units

Students learn and practice programming techniques on the MA2 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.

Prerequisites: 54-337 or 54-349

54-527 Automated Lighting Workshop

Spring

In the spring semester Automated Lighting Workshop course will consist of seven distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year Eos Family consoles and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will engineer the automated lighting rig that will be used for the summer and fall of 2020 in the Wells Video Studio. The fifth module will be a continuation of programming on the Hog4 console, concentrating on preparing students for the national Hog Factor competition. Module six will be an introduction to the Vx76 line of control consoles. In the seventh module students who have experience on the GrandMA2 line of consoles may continue the development of skills on that platform.

Prerequisite: 54-349

54-534 Costume Crafts: Theatrical Footwear

Spring: 5 units

This introductory course serves to instruct the student in the language, materials and processes of designing, creating and adapting footwear for the stage.

54-535 Costume Crafts: Fabric Modification

Spring: 5 units

This course is intended to introduce the student to processes of fabric modification that utilize techniques beyond painting and dyeing. Students will be encouraged to investigate the world of garment decoration and to actively explore a wide variety of processes and materials ranging from old world needle arts to modern crafts which utilize long established techniques in contemporary context.

54-536 Costume Crafts: Mask Making

Spring: 6 units

This course opens the world of mask creation to the adventurous student. A broad range of techniques are touched upon and explored allowing students to pick and choose those processes which appeal to their aesthetic and apply to their needs.

54-539 Fabric Dyeing I

Fall: 9 units

This course is designed to provide the student with an introductory level of instruction for a broad range of fabric dyeing and painting techniques. -Students should gain an understanding of the various dye classes and their safe use in dyeing fabric for the theatre. -The student should gain a full comprehension of the processes of each of these classes, including common terminology, and be able to correctly enumerate steps in the processes. -The student should be able to match the appropriate product to the demands of the project. -The student should gain skills necessary to manipulate the dye process to achieve desired results including exercising their understanding of color theory. -The student should gain a basic understanding of several specialty dye techniques that could excite further exploration.

54-548 Sound Forum

Spring: 1 unit

Twice weekly meeting of all declared sound design majors to discuss production assignments and issues surrounding productions.

54-561 The Films of the Coen Brothers

Fall and Spring: 6 units

Films of the Coen Brothers

54-565 Dance/Light

Fall: 3 units

A practical application of the knowledge and skills learned in Dance Lighting Design 1+2. The class shares the experience of each student creating the lighting for at least one dance performance piece in the Dance/Light Concert.

Prerequisite: 54-524

54-585 Dramaturgy Capstone Thesis

Fall: 9 units

No course description provided.

54-587 Dramaturgy Production

Fall and Spring; 12 units

This course provides dramaturgy students with the opportunity to engage in production dramaturgy on a School of Drama production. Expectations and tasks for these courses will be determined in consultation with the advisor on the production, and may include, but are not limited to: script preparation and analysis, rehearsal dramaturgy, gathering and curating of materials for the director, designers, and actors, lobby display curation and creation, the writing of a program note, audience outreach, facilitation of talkbacks and pre-show discussions, and other dramaturgical tasks/activities as needed for a particular production.

54-588 Dramaturgy Production III

Spring

For Dramaturgy majors.

54-590 The Post Apocalypse on Film

Spring; 6 units

This course will survey cinematic treatments of the end of civilization from a wide variety of filmmakers. We will analyze the cultural, philosophical, mythical and political elements of each film. We will also discuss the technical and artistic aspects in order to better understand the genre and filmmaking in general. The goal is for each student to develop ways to think critically about film.

54-592 Costume Crafts: Theatrical Armor

Fall; 5 units

This mini course introduces the student to the world of armor creation for the stage. Techniques covered range from traditional to revolutionary and provide the student with a breadth of possibilities geared toward solving the general conundrum of successful armor for the theatrical production. Prerequisite: 54-538

54-593 Stanley Kubrick and His Films

Intermittent; 6 units

Stanley Kubrick and His Films Stanley Kubrick and His Films will explore the amazing diversity in this excellent film director's output from 1967-1999. The course will emphasize the psychological and moral issues raised in his films. And the course will focus on his camera techniques, his use of sound and music, and other remarkable innovative elements. With each film, Kubrick seems to re-invent himself, expanding the dimensions of film art. Films that will be shown in class include: "Paths of Glory" (1957), "Lolita" (1962), "Dr. Strangelove" (1964), "2001: A Space Odyssey" (1968), "A Clockwork Orange" (1971), "Barry Lyndon" (1976), "The Shining" (1980), "Full Metal Jacket" (1987) and "Eyes Wide Shut" (1999).

54-599 Woody Allen and Mel Brooks films

Fall; 6 units

TBA

54-617 Independent Study in Dance

Fall and Spring

Independent Study in Dance with faculty approval.

54-633 The Basics of Self-Producing for Theater Artists

Spring; 6 units

Is self-producing for you, or do you prefer to use other people's resources? Basics of Producing for Theater Artists will introduce the mechanics of getting your work to the spectator while creating a sustainable life as an artist. We'll investigate old models and new platforms to help you find the location and the recipe for your unique mission. We will walk through budgeting, fundraising, marketing, contracts, rights, risks, and the audience of the future. As a final project, you will assemble a package you can hand to a potential funder that explains why your theater is needed to fill a void in the culture, and why no one is better suited to do it.

54-648 And One More Thing

Fall; 3 units

Technical Direction alumni make guest appearances to discuss topics they wish had been covered as part of the program (or even to make the occasional correction).

Prerequisite: 54-777

54-666 Production Audio

Spring

Introduction to the theories and technologies used in sound system design for theater and live entertainment. Sound Majors: Register for Section A, 6 Units Non-Majors: Register for Section B, 4 Units

54-672 Production Prep: Sender

Fall and Spring

Production Preparation is a required course and is a core component of the curriculum for all drama directing, dramaturgy, production, and design students. The production experience provides students with experience in the following areas: directing; dramaturgy; production management; stage management; production run work; stage operations; design of scenery, costumes, lighting, sound, and video/media; costume construction; prop construction; scenery construction; sound and video and media technology; and scenic painting. Fully participating in these experiences will facilitate students future success in the School of Drama as well as in the profession.

54-711 The Dye Room in Practice: Exploration in Practical Dyeing for Theatrical Artisan

Spring; 3 units

An Exploration in Practical Dyeing for the Theatrical Artisan

54-714 Costume Rendering

Spring; 9 units

This fast-paced course focuses on techniques and exercises specific to the development of versatile costume renderings enhanced by the mediums used in the creation. A variety of mediums and methods are explored including colored pencil, marker, ink, Doctor Martin's dyes, watercolor and acrylic as well as transfer drawings, resists and the use of a range of techniques. Color, texture, pattern, nude and clothed human models are carefully studied and rendered. Students also apply course techniques to the development of designs for production and portfolio preparation. PRE-REQUISITES: Drawing for the Theatrical Designer, Major in Design Option of School of Drama FOR: Graduate and Undergraduate Design Costume Majors only. Instructor Approval required. Prerequisite: 54-811 Prerequisite: 54-811

54-721 Graduate Directing: Text to Stage

Spring; 9 units

TBD

54-722 Graduate Directing: Text to Stage

Fall; 9 units

Text to Stage is a studio laboratory course for graduate CMU MFA directing students.

54-729 Automated Lighting Workshop

Fall and Spring

In the spring semester of the 2019/2020 academic year the Automated Lighting Workshop course will consist of seven distinct modules. The first will focus on the operation and maintenance of equipment that falls into the category of automated lighting. The second module will focus on the programming of media servers using lighting consoles. This year Eos Family consoles and MBox will be used. The third module will concentrate on the development of previsualization skills using LightConverse software. In the fourth portion of the class students will engineer the automated lighting rig that will be used for the summer and fall of 2020 in the Wells Video Studio. The fifth module will be a continuation of programming on the Hog4 console, concentrating on preparing students for the national Hog Factor competition. Module six will be an introduction to the Vx76 line of control consoles. In the seventh module students who have experience on the GrandMA2 line of consoles may continue the development of skills on that platform.

Prerequisite: 54-771

54-755 Drama Practicum

Summer; 3 units

This course provides 3 units of pass/fail credit for students participating in a drama related internship. The student must be registered for this course during the internship, in order to earn the credit. At the end of the term, the student's supervisor must email the academic advisor with a brief statement describing the student's activities, and an evaluation of the student's performance. Students are required to submit a statement, reflecting on insights gained from the internship experience. Upon receipt of both statements, the academic advisor will assign a grade of either P or N, depending on the outcome.

54-756 Theatre for the Ear

Spring; 6 units

Survey of aural storytelling with technology focusing on forms with no visual component. Topics include the history of radio drama to present day, radio sound art, cut-up and tape manipulation, comedy records and podcast dramas. Prerequisites: 54-767 Graduate Conceptual Sound Design 1 and amp; 54-768 Graduate Conceptual Sound Design 2 OR 54-791 Playwriting I. Restrictions: The course is open to Graduate Sound Design majors, Graduate Dramatic Writers or with permission of the instructor.

54-759 Working with Dramaturgs

Intermittent: 3 units

This mini-2 course enrolls writers with fully drafted dramatic works in progress and pairs them with student dramaturgs to advance the development of those works according to the writers' goals. Students develop collaborative skills and understanding of the role a dramaturg can play in new play development. Required of Dramatic Writing graduate students; open to other writers with instructor permission.

54-760 Grad Leadership Workshop: Ethics & Innovation

Intermittent: 6 units

This course will be an exploration of both innovative strategies and the ethics of leadership within the performing arts. It will build on the management principles covered in foundational courses and is designed to offer the student an approach to leadership development that is tailored to the individuals strengths and needs as well as their role within theatrical organizations. For PTM students only or with permission from the instructor. Prerequisite: 54-749

54-766 Introduction to Sound Design for Theatre

Spring: 6 units

Students explore the basic principles and theories of sound design from technical, psychological and aesthetic standpoints. Course work includes instruction in the controllable properties of sound, practical planning of sound plots, cue creation, and the design process. Restrictions: Open to all Graduate Drama Majors, CFA graduate students or with permission of instructor.

54-773 Couture Sewing Techniques

Intermittent: 9 units

This course is designed to help the student gain an understanding of and appreciation for high-end sewing and finishing techniques and how these techniques improve the quality of the clothing they are employed in. -The student should gain a comprehension of the terminology commonly used in couture sewing and high-end finishing. -The student should gain a full comprehension of the process of each of these techniques and be able to logically enumerate steps in the full process involved with each technique. -The student should be able to appropriately apply each technique and distinguish between techniques when making choices in the sewing process.

54-780 Fabric Painting

Spring: 9 units

This course is structured as a lecture/demonstration and lab employing the principles of fabric painting/printing techniques, fabric painting/printing materials and the practical use of these techniques and materials. The student should learn the basic concepts behind each of the covered processes, the materials and alternate methods involved with each process, and introductory concepts behind pattern registration. Additionally, the world of breakdown and distressing is covered in an ongoing exercise that spans the duration of the semester. Prerequisite: 54-845

54-795 Costume Crafts: Mold Making and Casting

Spring: 6 units

This course is designed to introduce the student to a wide variety of molding and casting techniques that might be encountered in the costume crafts area. Upon completion of this course students should understand basic products and processes available to them to enhance either their design work or their production capabilities. By no means is this an exhaustive survey and further study is encouraged.

54-796 The Basics of Self-Producing: How to Put Up Your Show in NYC and Get It Reviewed

Intermittent: 6 units

For any actor/writer/director/theatre artist in New York City, the time between jobs can feel stressful and frustrating. Self-producing is the quickest way to get your work on stage without permission from anyone else or having to adhere to anyone else's restrictions. From blurbs to budgets to rehearsal space to press releases to equity paperwork, this course covers everything you need to know in order to get your work produced and noticed in New York City without breaking the bank. This course will draw from readings on independent theatre, interviews with working independent producers in New York, and the working experience of Anderson Cook, author/producer of *The Disembodied Hand That Fisted Everyone to Death - the Musical!*, *Blatantly Blaine*, *Pop Punk High*, *Donny and Kelly Save the Slumber Valley ASPCA*, and more - all produced and reviewed in NYC.

54-815 Graduate Negotiation and Conflict Management

Fall: 3 units

This class is a focused exploration of the process of negotiating, both formally and everyday. We will examine interactions on all levels and environments, with an evaluation of tactics, strategies and the measure of success. From there, the class expands into the nature of conflicts and the manager's role in identifying and confronting them. Throughout the class, we hope to find solutions to implement in our lives and work. In-class exercises and role play will be a fundamental part of class activity.

54-819 Figure Drawing

Fall and Spring: 3 units

Costume Majors have priority, then Design Majors. This course explores the realistic and expressive depiction of the human form primarily in two dimensional media. Working primarily from the live model, exercises will be undertaken that address gesture, proportion, movement, anatomy and structure, composition and expressive form. Students will experience a variety of media and formal approaches to the figure, working from nude, draped, and clothed male and female models. A primary goal of the class is to develop the ability to create the human figure from imagination, based on intensive empirical study of the forms and structures of the human body from life.

54-832 Scenic Design: Design for Spaces

Spring: 4.5 units

A3: Design for Live Spaces: Scenic Design is a course that focuses on creating design within the format of live performance. The projects will be varied and will include new works, existing texts and other innovative forms of live design within the community. A4: Design for Screen Spaces: Scenic Design is a course that focuses on design for the screen. The projects may alternate between TV and Film design depending on the year. Industry professionals will be part of the course experience, giving students real-time knowledge. Projects will build towards a portfolio of work for use in the industry. This course focuses on developing the design tools in areas such as: research, collage assembly, model making, storyboards and creation of a short reel amongst other things.

54-880 Special Topics in Media: Mediated Reality

Spring: 10 units

Mediated Realities is an advanced studio course that investigates the potential applications of mediated-reality technologies and location-based interactivity for storytelling, site-specific art-making, and live performance (broadly defined). Converging trends in cultural production, mobile computation, and media technologies present new affordances for artists and designers to shape location-based experiences. Studio work engages a breadth of strategies in post-media aesthetics, as related to one's experience and understanding of place. Trans-media storytelling, real-time graphics, machine learning, gamification, locative artworks, augmented reality and powerful portable media devices present opportunities for artists and designers to create experiences that heighten multisensory experience by merging live performance and participant interaction with systems for digital information, imagery, and 3D visualization - all ubiquitously available in low-cost and widely distributable formats (e.g. apps, mobile web sites). The course frames technological experimentation in the context of 1970's Land Art, Happenings, Fluxus games, Performance Art, Expanded Cinema, and the unresolved theoretical issues emerging from this rich period in American history - site specificity, competing definitions of "community," the effects of media and representation, audience/performer dynamics, and the nature and limits of the art work. Reading discussions, site visits, and presentations from outside experts (CMU faculty, visiting artists) will expose a range of relevant topics, disciplinary and creative perspectives, and potential avenues for investigation. Specific areas of focus will include Pittsburgh history, local ecological dynamics, labor history and the effects of technology on the landscape and lives of Pittsburgh's population.

54-884 Graduate Digital Narratives

Fall: 5 units

This course combines options from the School of Drama in a unique configuration: through working collaboratively across disciplines, students will investigate innovative approaches to contemporary theater and new ways of storytelling. Contemporary techniques for ensemble creation, devising and media integration will be explored through exercises, readings, and viewing of other artist's work. This Fall the course will explore the wide variety of digitally mediated forms for online, remote and distanced work - techniques of collaboration, creation and experiencing of performance focused work. We will pursue multiple techniques for cross-platform storytelling, drawing from students' lived experiences to engage the current political and social milieu via multiple digital and mediated systems. Experimental and devised processes of theater making have long mined the complex relationship between the form and the content of an artwork - how can we do so in pursuit of a critical/political perspective? Students will become familiar with contemporary and historical companies who work this way and through small group in-class workshops create new narrative experiences and share them with the larger class. Through embracing these tools and forms, we utilize the theatrical conversation to engage in artistic discourse to discover new complexities of meaning. We invite students to come explore these possibilities in a spirit of experimentation and group exploration.

54-905 Ear Training

Spring: 1 unit

Ear Training for sound designers and audio technologists. Introduction and development of skills and techniques for discerning, measuring and expressing the physical qualities of sound with accuracy and sensitivity. Topics include recognizing frequencies (1/3 octave and dual-octave) and analyzing effects and processing (pitch, amplitude, time domain and timbral). This course is open to Drama Sound Design majors/minors, Music Technology major/minors or by permission of the instructor.

54-929 Writing for Television

Spring: 9 units

TBD

54-939 Entertainment Lighting Programming

Fall: 9 units

Students learn and practice programming techniques on the MA2 series of lighting control consoles. Advanced programming techniques are explored, including media server control and user-defined commands for the console. Different applications are introduced, but the primary focus is on programming for live music performance.

Prerequisites: 54-771 or 54-837

54-964 Graduate Scenic Design: Moving the Musical

Fall: 5 units

Designing scenery for a musical presents a number of specific and unique issues, often quite different than designing straight play. Addressing not only the story and the meaning of the piece is of course important but one must pay close attention to the style of the music and the way the songs are incorporated into the text. How do these elements help to tell the story? This course will allow you to explore how scenery moves and the ways in which it can enhance a text.

54-972 PTM Professional Practice

Fall: 3 units

A seminar about issues surrounding a career as a technical manager. In a series of presentations and discussions students will encounter tools and strategies for job seeking and personal promotion. Guest lecturers will present materials on professional obligations like insurance and taxes and non-salary compensation like retirement and health benefits.

54-973 Costume Production Thesis

Fall and Spring: 12 units

TBD

54-997 Sound Design For Interactive Environments

Spring: 9 units

This course will examine the process, execution and implementation of sound design for interactive and non-linear storytelling paradigms. Emerging trends in immersive theater, gaming, installation art and multi-media place unique demands on the sound designer both in terms of content and delivery. The student will explore how these demands effect the fundamental processes of design, development of content and flexible delivery systems. Through a combination of directed readings, exploration of current and emerging trends, and project assignments the student will be encouraged to experiment and explore design modes and methodologies that support this flexible method of storytelling.

Prerequisites: 54-867 or 54-868

54-998 Special Topics in Sound Design

Intermittent: 9 units

A one semester course covering various rotating topics including the history and critical theories of film sound design, the history of sound recording and technology, Foley sound, recording and editing techniques, and 5.1 audio.

Prerequisites: 54-867 Conceptual Sound Design. Restrictions: The course is open to Drama sound design majors and minors, Music Technology majors and minors or by permission of the instructor.

Prerequisite: 54-867

School of Music

Joanna Bosse, Interim Head
 Location: Hall of Arts 102
www.cmu.edu/cfa/music (<http://www.cmu.edu/cfa/music/>)

The School of Music at Carnegie Mellon University offers the best aspects of conservatory training within a great university, combining preparation for a lifetime in performance, composition, electronic music, or music and technology with the advantages of learning in an intense academic environment. Every student in the School of Music is a performance, composition, electronic music, or music and technology major. The School of Music is an accredited institutional member of the National Association of Schools of Music.

Each performance major is challenged to develop through individual instruction with a master teacher. The School's relationship with the renowned Pittsburgh Symphony Orchestra is among the strongest conservatory-symphony orchestra relationships in the United States, and Pittsburgh's uniquely strong sense of musical community fosters close relationships with the Pittsburgh Opera, Pittsburgh Chamber Music Society, and a host of other professional musical organizations.

Regular performing ensembles include the Carnegie Mellon Philharmonic, Wind Ensemble, Bagpipe and Drum Band, Baroque Ensemble, Contemporary Ensemble, Exploded Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, and Opera. Some of the School's ensembles are instrument specific: Chamber Music ensembles and the Percussion Ensemble, among others. Opportunities for performance are stressed - undergraduate performance majors perform junior and senior recitals, chamber music is publicly presented, frequent performance opportunities on and off campus are provided, and community outreach is vigorously supported.

The School of Music has an intense commitment to new music, led by composition faculty, conductors who devote fully rehearsed cycles of the Philharmonic to works by student composers, and studio faculty whose own performing careers regularly feature new works, and including regular performances of student works in almost every Contemporary Ensemble Program, frequent opportunities with the Wind Ensemble and Chorus, and inclusion on student recitals. The School's state-of-the-art recording facilities are an especially important resource for composers beginning their public careers.

All teaching is entrusted to professional faculty — there are no assistant studio teachers or doctoral teaching fellows — and specialists in Musicology, Theory, Analysis, Counterpoint, Composition, Computer Music, Electronic Music, Eurhythmics, Solfege, Music Education, Pedagogy, Collaborative Piano and Coaching, Acting and Movement, Diction, Literature and Repertoire, Baroque Music, Chamber Music, Conducting, and Sound Recording and Production provide a broad and rich platform for comprehensive musical preparation. At the same time, the university provides the greatest possible support for students combining their majors with minors in all disciplines, unique joint degree programs, and double major programs. These opportunities significantly increase a student's career options and marketability in the changing professional world of music.

School of music Facilities

The teaching facilities of the School of Music are located on the ground, main, and mezzanine floors of the College of Fine Arts, on the ground, main, and second floors of the Hall of Arts, on the first floor of Margaret Morrison Hall, and in WQED Studio B. Teaching, rehearsal, and practice rooms are equipped with Steinway pianos. Music students also have access to a state-of-the-art recording studio and music technology cluster. Performances take place in Kresge Recital Hall, Carnegie Music Hall, Alumni Concert Hall, and Mellon Institute Auditorium. The Hunt Library houses a fine collection of books, records, and scores. Listening and conference rooms are also available in the library.

School of Music Options

The School of Music offers a Bachelor of Fine Arts in the following areas:

- Performance (Instrumental, Organ, Piano, Voice)
- Composition
- Electronic Music

The School of Music jointly with the School of Computer Science and the Carnegie Institute of Technology offers a Bachelor of Science in the following area:

- Music and Technology

To earn a Bachelor's degree in any of these options, a candidate must satisfactorily fulfill all the requirements of the School of Music.

Within the options listed above eligible students may elect specializations in the following areas:

- Dalcroze Eurhythmics Certificate
- Piano Pedagogy Certificate
- Collaborative Piano Minor
- Conducting Minor
- Music Education Minor
- Music Technology Minor
- Music Theory Minor
- Sonic Arts Minor

Dalcroze Eurhythmics Certificate

This program is designed to prepare teachers in the Dalcroze approach to music learning. The course of study includes eurhythmics, piano improvisation, and Dalcroze pedagogy. Carnegie Mellon undergraduates may enter the Dalcroze Training Program during their junior year. However, the certificate will be granted only upon completion of their undergraduate degree. This program is recommended particularly to students who would like to incorporate Dalcroze principles into their teaching and to those who want to obtain more experience in this field.

Piano Pedagogy Certificate

A two-year program leading to certification in piano pedagogy is open to current Carnegie Mellon keyboard majors. They learn to teach piano in a closely supervised environment of class piano instruction. This program has received national acclaim as a model of excellence, with Carnegie Mellon children consistently capturing prestigious awards in national piano competitions.

Collaborative Piano Minor

The collaborative piano minor consists of a six-semester sequence of courses designed to give the students experience with instrumentalists and vocalists. There are individual coaching sessions as well as practical experience in instrumental and vocal studios.

Conducting Minor

This minor is designed for students who are interested in acquiring conducting skills, in anticipation of either graduate study in conducting or a music education career. It includes required courses in conducting techniques for both choral and instrumental ensembles, orchestration, score reading/keyboard harmony, and elective courses in instrumental and vocal methods, diction, and literature and repertoire.

Music Education Minor

This minor is designed for students who are interested in music education, who may wish to complete the requirements for music education certification. Students who complete the requirements for music education certification and pass the Praxis tests will receive Pennsylvania state certification in music (K-12), which is recognized in almost all other states.

Music Technology Minor

The student will take a series of courses which may include electronic and computer music, recording technology, the physics of musical sound, and computer programming. A rich computer music research environment enables talented students to work as programmers with outstanding faculty researchers, whose current projects are gaining international recognition in the areas of computer music and artificial intelligence.

Music Theory Minor

This minor is designed for students who are interested in advanced theory and analysis skills, in anticipation of either graduate study in theory or graduate study that requires a substantial level of theory knowledge. The

student will take advanced theory and analysis courses and also support courses in the physics of musical sound and the psychology of music.

Sonic Arts Minor

Students in this minor will explore the processes and products of digital sound and music. They will receive basic training in key component areas: principles of computer music, hybrid instrument building, concepts in sound design. Combining this training with courses that bring together experts from many disciplines, they will create experimental music or explore new, technology-enabled, applications and markets for sound design, music creation, and performance.

Performances and Activities of the School of Music

The School of Music sponsors performances, master classes, and lectures by outstanding national and international guest artists. Announcements of faculty, student, and guest performances are published for the students and the community.

General Requirements for BFA Candidates

Candidates for the Bachelor of Fine Arts degree in composition are required to complete a composition for orchestra in their senior year.

Candidates for the Bachelor of Fine Arts degree in electronic music are required to complete an ambitious capstone project in their senior year that may take the form of an evening length concert, a multimedia experience, an interactive exhibition or app, or some other project that exhibits the student’s research and creative output.

Candidates for the Bachelor of Fine Arts degree in performance are required to give public performances in their junior and senior years. Candidates for the Bachelor of Fine Arts degree in string performance are required to give public performances in their sophomore, junior, and senior years.

Candidates for the Bachelor of Fine Arts degree in performance are required to pass one semester (piano majors must pass two semesters) of a course that includes experience with pedagogy for their major studio area.

- Instrumental majors must take the class for their area to fulfill the Pedagogy Course requirement on the Instrumental curriculum (57-023 Bassoon Studio Performance Class, 57-448 Brass Pedagogy, 57-022 Clarinet Studio Performance Class, 57-018 Double Bass Studio Performance Class, 57-020 Flute Studio Performance Class, 57-021 Oboe Studio Performance Class, 57-030 Percussion Studio Performance Class, 57-016 Viola Studio Performance Class, 57-015 Violin Studio Performance Class, 57-437 Literature and Repertoire).
- Bagpipe, organ and saxophone majors must fulfill the pedagogy requirement as part of satisfying all demands outlined in their Major Studio syllabi, 57-522 Major Studio (Bagpipe), 57-502 Major Studio (Organ) and 57-514 Major Studio (Saxophone).
- Piano majors must take 57-273 Piano Pedagogy I and 57-274 Piano Pedagogy II.
- Voice majors must take 57-010 Voice Studio Performance Class.

Candidates for the Bachelor of Fine Arts degree in applied areas other than piano are required to pass a piano proficiency test.

Candidates for Bachelor of Fine Arts degrees in composition and performance are required to pass four repertoire proficiency tests, and to pass a major choral ensemble or a major instrumental ensemble as assigned and to pass Convocation every semester of residence in the School of Music.

Candidates for the Bachelor of Fine Arts degree in electronic music are required to to pass Exploded Ensemble or Contemporary Ensemble as assigned every semester of residence and to pass Convocation four semesters of residence in the School of Music.

BFA Curriculum

The music curriculum is based on the following five building blocks:

1. Studio
2. Theory
3. History
4. Ensemble
5. Academics

1. Studio — This is the heart of the school. Students receive individualized instruction with senior faculty in their major area of study: performance or composition or electronic music.

2. Theory — These courses are designed to help students develop listening skills, to acquire theoretical knowledge, to recognize structural techniques and manipulate technological resources. It includes courses in sight-reading, ear-training, eurhythmics, harmony, contrapuntal techniques, analysis of musical forms, 20th-21st century techniques, orchestration, score reading, and electronic and computer music. One music support course in the piano, organ, and instrumental curricula must be a theory course.

3. History - These courses cover in depth the music of the western world and survey the styles and musical structures of non-western music.

4. Ensemble — This area includes student participation in some of the following ensembles: Carnegie Mellon Philharmonic, Wind Ensemble, Bagpipe and Drum Band, Baroque Ensemble, Contemporary Ensemble, Exploded Ensemble, Jazz Orchestra, Jazz Vocal Ensemble, Chorus, Opera, Chamber Music ensembles, and Percussion Ensemble.

5. Academics — The School of Music requires general studies courses (academic courses outside of the School) and elective courses for graduation. These accumulated credits may be applied to minors or majors in other disciplines. Exceptional students in good academic and musical standing within the School are permitted to take additional courses beyond the number required for graduation. There is no charge for extra credits taken at Carnegie Mellon. One elective course in the performance curricula must be a course that includes experience with pedagogy for the student’s major studio area.

| Minimum units required for B.F.A. in Music | |
|---|------------|
| Voice majors | 432 |
| Electronic Music majors | 406 |
| Composition majors | 392 |
| Instrumental, Organ, and Piano majors | 386 |

Piano

First Year

| Fall | | Units |
|--------|--|-----------|
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-196 | Collaborative Piano Skills I | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-101 | Introduction to Music Technology | 6 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| | | 55 |

| Spring | | Units |
|--------|---|-----------|
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-197 | Collaborative Piano Skills II | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfege II | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-283 | Music History I | 9 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |
| | | 55 |

Second Year

| Fall | | Units |
|--------|----------------------|-------|
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |

| | | |
|--------|---|---|
| 57-672 | Chamber Music: Woodwind and Mixed | 3 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfege III | 3 |
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-284 | Music History II | 9 |
| xx-xxx | General Studies Course | 6 |

49

| | | |
|--------|--|---|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-672 | Chamber Music: Woodwind and Mixed | 3 |
| 57-408 | Form and Analysis | 6 |
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfege IV | 3 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-285 | Music History III | 9 |
| xx-xxx | Elective Course | 6 |

49

Third Year

| | | |
|--------|---------------------------------------|-------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-672 | Chamber Music: Woodwind and Mixed | 3 |
| 57-273 | Piano Pedagogy I | 6 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 6 |

52

| | | |
|--------|---------------------------------------|----|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-672 | Chamber Music: Woodwind and Mixed | 3 |
| 57-274 | Piano Pedagogy II | 6 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 6 |

52

Fourth Year

| | | |
|--------|---------------------------------------|-------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-xxx | Performance Elective | 9 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |

43

| | | |
|--------|---------------------------------------|----|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-501 | Major Studio (Piano) | 9 |
| 57-xxx | Performance Elective | 9 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |

43

Organ

First Year

| | | |
|--------|--|-------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-101 | Introduction to Music Technology | 6 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |

55

| | | |
|--------|---|---|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfege II | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-283 | Music History I | 9 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |

55

Second Year

| | | |
|--------|---|-------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfege III | 3 |
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-284 | Music History II | 9 |
| xx-xxx | General Studies Course | 6 |

49

| | | |
|--------|--|---|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-408 | Form and Analysis | 6 |
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfege IV | 3 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-285 | Music History III | 9 |
| xx-xxx | Elective Course | 6 |

49

Third Year

| | | |
|--------|--|-------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-459 | Score Reading for Composition Majors and Conducting Minors | 6 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| 57-xxx | Pedagogy Course | var. |

| | | |
|--------|------------------------|---|
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |

46

Spring

| | | |
|--------|---------------------------------------|----|
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 9 |

46

Fourth Year

Fall

| | | Units |
|--------|---------------------------------------|-------|
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Performance Elective | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |

43

Spring

| | | |
|--------|---------------------------------------|----|
| 57-100 | Convocation | 1 |
| 57-502 | Major Studio (Organ) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Performance Elective | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |

43

Voice

First Year

Fall

| | | Units |
|--------|----------------------------------|-------|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-467 | Production: Crew | 3 |
| 57-191 | Keyboard Studies | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfège I | 3 |
| 82-161 | Elementary Italian I | 12 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 57-240 | Acting I | 3 |
| 57-111 | Movement and Dance I | 3 |

60

Spring

| | | |
|--------|----------------------------------|----|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-468 | Production: Crew | 3 |
| 57-191 | Keyboard Studies | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfège II | 3 |
| 82-162 | Elementary Italian II | 12 |
| 57-221 | Italian Diction | 3 |
| 57-241 | Acting II | 3 |

| | | |
|--------|-----------------------|---|
| 57-112 | Movement and Dance II | 3 |
|--------|-----------------------|---|

60

Second Year

Fall

| | | Units |
|--------|--|-------|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfège III | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 82-121 | Elementary German I | 12 |
| 76-101 | Interpretation and Argument | 9 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-339 | Acting III | 3 |
| 57-211 | Movement and Dance III | 3 |

63

Spring

| | | |
|--------|--|----|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfège IV | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-283 | Music History I | 9 |
| 82-122 | Elementary German II | 12 |
| 57-223 | German Diction | 3 |
| 57-408 | Form and Analysis | 6 |
| 57-340 | Acting IV | 3 |
| 57-212 | Movement and Dance IV | 3 |

66

Third Year

Fall

| | | Units |
|--------|---|-------|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-xxx | Production Course | 6 |
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-284 | Music History II | 9 |
| 82-101 | Elementary French I | 12 |
| 57-101 | Introduction to Music Technology | 6 |

54

Spring

| | | |
|--------|--|----|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-xxx | Production Course | 6 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-285 | Music History III | 9 |
| 82-102 | Elementary French II | 12 |
| 57-222 | French Diction | 3 |

51

Fourth Year

| Fall | | Units |
|--------|---|-----------|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-xxx | Production Course | 6 |
| 57-473 | Survey of Vocal Repertoire I | 3 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |
| xx-xxx | Elective Course | 3 |
| | | 39 |

| Spring | | Units |
|--------|----------------------------------|-----------|
| 57-100 | Convocation | 1 |
| 57-500 | Major Studio (Voice) | 9 |
| 57-593 | Vocal Coaching | 1 |
| 57-010 | Voice Studio Performance Class | 1 |
| 57-417 | Major Vocal Performance Ensemble | 6 |
| 57-xxx | Production Course | 6 |
| 57-474 | Survey of Vocal Repertoire II | 3 |
| xx-xxx | Elective Course | 12 |
| | | 39 |

Instrumental

A string major must also complete two semesters of Chamber Music in the sophomore year.

First Year

| Fall | | Units |
|--------|--|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-101 | Introduction to Music Technology | 6 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| | | 55 |

| Spring | | Units |
|--------|---|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfege II | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-283 | Music History I | 9 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |
| | | 55 |

Second Year

| Fall | | Units |
|--------|--|-------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfege III | 3 |

| | | |
|--------|---|-----------|
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-284 | Music History II | 9 |
| xx-xxx | General Studies Course | 6 |
| | | 49 |

| Spring | | Units |
|--------|--|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-408 | Form and Analysis | 6 |
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfege IV | 3 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-285 | Music History III | 9 |
| xx-xxx | Elective Course | 6 |
| | | 49 |

Third Year

| Fall | | Units |
|--------|---------------------------------------|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Chamber Music | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| 57-xxx | Pedagogy Course | var. |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 6 |
| | | 46 |

| Spring | | Units |
|--------|---------------------------------------|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Chamber Music | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 6 |
| | | 43 |

Fourth Year

| Fall | | Units |
|--------|---------------------------------------|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Chamber Music | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |
| | | 40 |

| Spring | | Units |
|--------|---------------------------------------|-----------|
| 57-100 | Convocation | 1 |
| 57-xxx | Studio | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Chamber Music | 3 |
| 57-xxx | Music Support Course (Theory/History) | 12 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 3 |
| | | 40 |

Composition

First Year

| Fall | | Units |
|--------|----------------------------|-------|
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |

| | | |
|--------|--|-----------|
| 57-191 | Keyboard Studies | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-101 | Introduction to Music Technology | 6 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| | | 55 |

| | | |
|--------|---|-----------|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfege II | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-283 | Music History I | 9 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |
| | | 55 |

Second Year

| | | |
|--------|---|-----------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfege III | 3 |
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-284 | Music History II | 9 |
| 57-257 | Orchestration I | 6 |
| xx-xxx | Elective Course | 6 |
| | | 55 |

| | | |
|--------|--|-----------|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-191 | Keyboard Studies | 3 |
| 57-408 | Form and Analysis | 6 |
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfege IV | 3 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-285 | Music History III | 9 |
| 57-271 | Orchestration II | 6 |
| 57-258 | 20th-21st Century Techniques | 6 |
| | | 55 |

Third Year

| | | |
|--------|-------------------------------|-----------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-234 | Performance for Composers | 3 |
| 57-332 | Introduction to Conducting | 6 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-xxx | Music Support Course | 6 |
| xx-xxx | General Studies Course | 12 |
| | | 43 |

| | | |
|--------|----------------------------|---|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-236 | Performance for Composers | 3 |

| | | |
|--------|--|-----------|
| 57-336 | Instrumental/Choral Conducting | 6 |
| 57-459 | Score Reading for Composition Majors and Conducting Minors | 6 |
| 57-xxx | Music Support Course | 6 |
| xx-xxx | General Studies Course | 12 |
| | | 43 |

Fourth Year

| | | |
|--------|----------------------------|-----------|
| Fall | | Units |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Music Support Course | 6 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 12 |
| | | 43 |

| | | |
|--------|----------------------------|-----------|
| Spring | | |
| 57-100 | Convocation | 1 |
| 57-521 | Major Studio (Composition) | 9 |
| 57-4xx | Major Ensemble | 6 |
| 57-xxx | Music Support Course | 6 |
| xx-xxx | General Studies Course | 9 |
| xx-xxx | Elective Course | 6 |
| | | 37 |

ELECTRONIC MUSIC

First Year

| | | |
|--------|---|----|
| 57-100 | Convocation | 1 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 76-101 | Interpretation and Argument | 9 |
| 57-358 | Introduction to Electronic Music | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 57-421 | Exploded Ensemble | 6 |
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-191 | Keyboard Studies | 3 |
| | | |
| 57-100 | Convocation | 1 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-153 | Harmony II | 9 |
| 57-162 | Eurhythmics II | 3 |
| 57-182 | Solfege II | 3 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-191 | Keyboard Studies | 3 |

Second Year

| | | |
|--------|--|---|
| 57-100 | Convocation | 1 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-421 | Exploded Ensemble | 6 |
| 57-163 | Eurhythmics III | 3 |
| 57-183 | Solfege III | 3 |
| 57-257 | Orchestration I | 6 |
| 57-xxx | Music Elective | 9 |
| 57-xxx | Electronic Music support course/Special Topics | 9 |
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-191 | Keyboard Studies | 3 |
| | | |
| 57-100 | Convocation | 1 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-421 | Exploded Ensemble | 6 |
| 57-408 | Form and Analysis | 6 |

| | | |
|--------|--|----|
| 57-164 | Eurhythmics IV | 3 |
| 57-184 | Solfege IV | 3 |
| 57-xxx | Electronic Music support course/Special Topics | 9 |
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-191 | Keyboard Studies | 3 |
| xx-xxx | General Studies Course | 10 |

Third Year

| | | |
|--------|---|----|
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-332 | Introduction to Conducting | 6 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 57-xxx | Electronic Music support course/Special Topics | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-173 | Survey of Western Music History | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |

| | | |
|--------|--|----|
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-359 | Audiovisual Composition | 9 |
| 57-xxx | Electronic Music support course/Special Topics | 9 |
| 57-421 | Exploded Ensemble | 6 |
| xx-xxx | General Studies Course | 10 |

Fourth Year

| | | |
|--------|--|----|
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-421 | Exploded Ensemble | 6 |
| 57-xxx | Electronic Music support course/Special Topics | 9 |
| xx-xxx | General Studies Course | 12 |
| 57-xxx | Music Elective | 9 |

| | | |
|--------|--|---|
| 57-523 | Major Studio (Electronic Music) | 9 |
| 57-560 | Electronic Music Seminar | 3 |
| 57-421 | Exploded Ensemble | 6 |
| 57-xxx | Electronic Music support course/Special Topics | 6 |
| xx-xxx | General Studies Course | 9 |
| 57-xxx | Music Elective | 9 |

Dalcroze Eurhythmics Certificate 33 units

| | | |
|--------|--|------|
| 57-465 | Eurhythmics Applications for Performing and Teaching | 6 |
| 57-466 | Eurhythmics Applications for Performing and Teaching | 6 |
| 57-691 | Dalcroze Pedagogy/Practice Teaching | 3 |
| 57-692 | Dalcroze Pedagogy/Practice Teaching | 3 |
| xx-xxx | Creative Movement/Choreography | 3 |
| 57-351 | Dalcroze Piano Improvisation | Var. |
| 57-641 | Dalcroze Research Paper | 3 |
| 57-642 | Dalcroze Research Paper | 3 |

Piano Pedagogy Certificate 36 units

| | | |
|--------|---------------------------------|---|
| 57-273 | Piano Pedagogy I | 6 |
| 57-274 | Piano Pedagogy II | 6 |
| 57-275 | Piano Pedagogy III | 6 |
| 57-276 | Piano Pedagogy IV | 6 |
| 57-429 | Beginning Piano for Children I | 6 |
| 57-449 | Beginning Piano for Children II | 6 |

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and

technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student's entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology 380

General Requirements 85 units

Seminar

| | | |
|--------|--|---|
| 57-570 | Music and Technology Seminar (8 semesters for a total of 8 units) | 1 |
|--------|--|---|

University

| | | |
|--------|---|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| xx-xxx | Global, Cultural, and Diverse Perspectives Course | 9 |

Humanities

| | | |
|--------|--|---|
| xx-xxx | Cognition, Choice and Behavior course | 9 |
| xx-xxx | English, History, Modern Languages, Philosophy, or Psychology course | 9 |

Mathematics

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |

Science

| | | |
|--------|------------------------------------|----|
| 33-114 | Physics of Musical Sound | 9 |
| 33-141 | Physics I for Engineering Students | 12 |

Electives 33 or 37 units

Music Core 81 units

| | | |
|--------|--|---|
| 57-152 | Harmony I | 9 |
| 57-153 | Harmony II | 9 |
| 57-408 | Form and Analysis | 6 |
| 57-151 | Counterpoint in Theory and Application | 6 |
| 57-258 | 20th-21st Century Techniques | 6 |
| 57-257 | Orchestration I | 6 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-190 | Repertoire and Listening for Musicians I | 3 |
| 57-289 | Repertoire and Listening for Musicians II | 3 |
| 57-290 | Repertoire and Listening for Musicians III | 3 |
| 57-181 | Solfege I | 3 |
| 57-182 | Solfege II | 3 |
| 57-183 | Solfege III | 3 |
| 57-184 | Solfege IV | 3 |
| 57-161 | Eurhythmics I | 3 |
| 57-162 | Eurhythmics II | 3 |
| 57-173 | Survey of Western Music History | 9 |

Music and Technology Core 121 units

| | | |
|--------|---|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-100 | Introduction to Electrical and Computer Engineering | 12 |
| 18-202 | Mathematical Foundations of Electrical Engineering | 12 |
| 18-290 | Signals and Systems | 12 |
| 57-101 | Introduction to Music Technology | 6 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

| | | |
|--------|------------------------------|----|
| 57-571 | Music and Technology Project | 12 |
| 57-572 | Music and Technology Project | 12 |

Concentration

Students complete either the Music Concentration or the Technical Concentration:

| | | |
|----------------------------|------------------------------|-----------------|
| Music Concentration | | 60 units |
| 57-5xx | Studio (4 semesters) | 36 |
| 57-4xx | Major Ensemble (4 semesters) | 24 |

| | | |
|--------------------------------|----------------------------------|-----------------------|
| Technical Concentration | | 58 or 56 units |
| 21-127 | Concepts of Mathematics | 12 |
| 15/18-213 | Introduction to Computer Systems | 12 |

AND EITHER:

| | | |
|---------------|---|----|
| 18-220 | Electronic Devices and Analog Circuits | 12 |
| 18-240 | Structure and Design of Digital Systems | 12 |
| 15-2xx/18-3xx | Electives in ECE or CS or above | 12 |

OR:

| | | |
|---------------|--|----|
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-323 | Computer Music Systems and Information Processing | 9 |
| 15-2xx/18-3xx | Electives in ECE or CS or above | 12 |

Minors

Minor in Collaborative Piano for Piano Majors in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

36 units Required Courses

| | | |
|--------|-------------------------|---|
| 57-381 | Collaborative Piano I | 6 |
| 57-382 | Collaborative Piano II | 6 |
| 57-383 | Collaborative Piano III | 6 |
| 57-384 | Collaborative Piano IV | 6 |
| 57-385 | Collaborative Piano V | 6 |
| 57-386 | Collaborative Piano VI | 6 |

18 units Electives

(choose from the following courses)

| | | |
|--------|--|---|
| 57-220 | English Diction | 3 |
| 57-221 | Italian Diction | 3 |
| 57-222 | French Diction | 3 |
| 57-223 | German Diction | 3 |
| 57-332 | Introduction to Conducting | 6 |
| 57-336 | Instrumental/Choral Conducting | 6 |
| 57-431 | Italian Literature and Repertoire | 3 |
| 57-432 | French Literature and Repertoire | 3 |
| 57-433 | Musical Theatre Literature and Repertoire | 3 |
| 57-434 | Musical Theatre Literature and Repertoire | 3 |
| 57-435 | German Literature and Repertoire | 3 |
| 57-436 | English/Contemporary Literature and Repertoire | 3 |
| 57-459 | Score Reading for Composition Majors and Conducting Minors | 6 |
| 57-607 | Vocal Methods | 3 |

Minimum units required for Collaborative Piano Minor: 54

Minor in Conducting for Students in the School of Music

Admission Requirements:

1. The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).
2. A 3.0 cumulative overall QPA and good academic standing are required.
3. In addition to passing the prerequisite courses listed below, the student must display superior solfege skills, by passing Advanced Solfege I and II with "A" or "B" grades or by passing Solfege I and II with "A" or "B" grades and with the recommendation of the student's solfege instructor; and the student must also pass Introduction to Conducting with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor.

ACADEMIC REQUIREMENTS:

1. Immediately after acceptance into the minor in conducting, the student must schedule an advising appointment with the faculty supervisor of the conducting minor.
2. Instrumental/Choral Conducting must be completed before the senior year with an "A" grade or with a "B" grade and with the recommendation of the student's conducting instructor before the student can register for the advanced conducting courses (see #3).
3. Conducting Practicum must be taken during the same semester as Independent Study in Conducting. Both courses must be taken after completing Introduction to Conducting and Instrumental/Choral Conducting.
4. A 3.0 cumulative overall QPA is required for graduation with the minor in conducting.

30 units Prerequisite Courses

| | | |
|--------|--|---|
| 57-152 | Harmony I | 9 |
| 57-153 | Harmony II | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-162 | Eurhythmics II | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |
| 57-191 | Keyboard Studies | 3 |

39 units Required Courses

Choose two of the following five courses immediately below as recommended by the faculty supervisor of the conducting minor:

| | | |
|--------|--|---|
| 57-360 | Brass Methods | 3 |
| 57-361 | Percussion Methods | 3 |
| 57-362 | Woodwind Methods | 3 |
| 57-363 | String Methods | 3 |
| 57-557 | Vocal Methods | 3 |
| 57-332 | Introduction to Conducting | 6 |
| 57-336 | Instrumental/Choral Conducting | 6 |
| 57-257 | Orchestration I | 6 |
| 57-459 | Score Reading for Composition Majors and Conducting Minors | 6 |
| 57-364 | Conducting Practicum | 3 |
| 57-618 | Independent Study in Conducting | 6 |

15 units Electives

(choose from the following courses)

| | | |
|--------|-----------------------------------|---|
| 57-220 | English Diction | 3 |
| 57-221 | Italian Diction | 3 |
| 57-222 | French Diction | 3 |
| 57-223 | German Diction | 3 |
| 57-258 | 20th-21st Century Techniques | 6 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-431 | Italian Literature and Repertoire | 3 |
| 57-432 | French Literature and Repertoire | 3 |
| 57-435 | German Literature and Repertoire | 3 |
| 57-607 | Vocal Methods | 3 |
| 57-491 | Solfege for Conductors I | 3 |

| | | |
|--|----------------------------|----|
| 57-492 | Solfege for Conductors II | 3 |
| 57-227 | Jazz Instrumental Ensemble | 3 |
| 57-230 | Baroque Ensemble | 3 |
| 57-231 | Chamber Ensemble | 3 |
| 57-420 | JIVE - CMU Jazz Choir | 3 |
| 57-423 | Repertoire Orchestra | 3 |
| Minimum units required for Conducting minor: | | 54 |

Minor in Music Education for Students in the School of Music

Admission Requirements:

The student must apply to the music education faculty no earlier than spring of the freshman year.

| | | |
|-----------------------------|-----------------------------|----------|
| Corequisite General Courses | | 45 units |
| 76-101 | Interpretation and Argument | 9 |
| 21-xxx | Mathematics Course #1 | 9 |
| 21-xxx | Mathematics Course #2 | 9 |
| 76-xxx | English Literature Course | 9 |

| | | |
|---------------------------|----------------------------------|----------|
| Corequisite Music Courses | | 18 units |
| 57-391 | Keyboard Studies (Music Ed) | 3 |
| 57-392 | Keyboard Studies (Music Ed) | 3 |
| 57-393 | Keyboard Studies Test (Music Ed) | 0 |
| 57-332 | Introduction to Conducting | 6 |
| 57-336 | Instrumental/Choral Conducting | 6 |

| | | |
|---------------------------|---|----------|
| General Education Courses | | 36 units |
| 57-331 | Principles of Education | 9 |
| 57-643 | Diverse Populations in Inclusive Settings | 9 |

| | | |
|---------------------------------|--|----------|
| Music Education Methods Courses | | 48 units |
|---------------------------------|--|----------|

General Methods Courses

| | | |
|--------|--------------------------------|---|
| 57-375 | Music in the Elementary School | 6 |
| 57-356 | Elementary Guided Teaching | 3 |
| 57-376 | Music in the Secondary School | 6 |
| 57-355 | Secondary Guided Teaching | 3 |

Applied Area Methods Courses

| | | |
|--------|--------------------|------|
| 57-207 | Music Studio | Var. |
| 57-360 | Brass Methods | 3 |
| 57-361 | Percussion Methods | 3 |
| 57-363 | String Methods | 3 |
| 57-362 | Woodwind Methods | 3 |
| 57-607 | Vocal Methods | 3 |

Band Methods Courses

Fundamentals of Marching Band is required. Stage Direction is optional.

| | | |
|--------|-------------------------------|---|
| 57-334 | Fundamentals of Marching Band | 3 |
| 57-370 | Stage Direction | 3 |
| 57-333 | Band and Choral Arranging | 6 |

| | | |
|----------------------------------|--------------------------------|----------|
| Music Education Teaching Courses | | 15 units |
| 57-603 | Practice Teaching (Elementary) | 6 |
| 57-604 | Practice Teaching (Secondary) | 6 |

| | | |
|---|--|-----|
| Minimum units required for Music Education Minor: | | 129 |
|---|--|-----|

Minor in Music Technology for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

| | | |
|----------------------|--|----------|
| Prerequisite Courses | | 18 units |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |

| | | |
|-------------------------|-----------------------------|----------|
| Sound Recording Courses | | 21 units |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

| | | |
|---|--|----------|
| Music Technology/Sound Courses (choose 3) | | 21 units |
|---|--|----------|

Choose at least three courses. One of the three courses must be either Introduction to Computer Music or Electronic and Computer Music. (Note that 15-112 is a prerequisite for 15-322; 57-101 or 57-171 is a prerequisite for 57-347.) Other courses may be taken with the permission of the music technology minor advisor.

| | | |
|--------|---|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-421 | Exploded Ensemble | 6 |
| 57-478 | Survey of Historical Recording | 6 |

| | | |
|--|--|----|
| Minimum units required for Music Technology Minor: | | 60 |
|--|--|----|

Minor in Music Theory for Students in the School of Music

Admission Requirements:

The student must apply to enter the program in the office of the Director of Student Services (HOA 141A).

| | | |
|----------------------|--|----------|
| Prerequisite Courses | | 18 units |
| 57-152 | Harmony I | 9 |
| 57-161 | Eurhythmics I | 3 |
| 57-181 | Solfege I | 3 |
| 57-189 | Introduction to Repertoire and Listening for Musicians | 3 |

| | | |
|---------------------------------------|--|----------|
| Upper Level Theory Courses (choose 3) | | 21 units |
|---------------------------------------|--|----------|

See theory courses on the Music Support Courses Two-Year Rotation list.

It is available on the Current Students website (<https://www.cmu.edu/cfa/music/current-students/>). A graduate course may be taken with the permission of the instructor.

| | | |
|------------------------------------|--|-----------|
| Graduate Theory Courses (choose 1) | | 6-9 units |
|------------------------------------|--|-----------|

See graduate theory courses on the Music Support Courses Two-Year Rotation list. It is available on the Current Students website (<https://www.cmu.edu/cfa/music/current-students/>). The course is to be chosen with the advisor's approval.

| | | |
|-----------------|--------------------------|----------|
| Support Courses | | 18 units |
| 33-114 | Physics of Musical Sound | 9 |
| 57-377 | Psychology of Music | 9 |

| | | |
|--|--|----|
| Minimum units required for Music Theory Minor: | | 63 |
|--|--|----|

Sonic Arts Minor – IDeATe

Sonic Art is a creative expression that uses sound as its primary medium. Just as visual artists create landscapes, portraits, and narratives through

light, color, and form, sonic artists craft transformative experiences through sound, noise, and music.

Students in the *Sonic Arts* minor explore the processes and products of digital sound design and music production. They receive basic training in key component areas: principles of computer music, sound synthesis, spatialization, and core practices in sound design. Combining this training with courses that bring together experts from many disciplines, they create experimental music and explore emerging applications and markets for sound design, music creation, and performance.

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDEaTe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 18-090 | Twisted Signals: Multimedia Processing for the Arts Other IDEaTe Portal Course by permission only. Consult the IDEaTe advisor. | 10 |

IDEaTe Sonic Arts Courses - Minimum of 27 Units

| | | Units |
|---------------|---|-------|
| 15-322 | Introduction to Computer Music | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-267 | Conceptual Sound Design | 9 |
| 54-509 | Theatrical Sound System Design 2 | 9 |
| 57-337 | Sound Recording | 6 |
| 57-344/60-407 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music portfolio required for registration | 9 |
| 57-359 | Audiovisual Composition | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-458 | Business of Music | 6 |

Additional course options as available. Please refer to the IDEaTe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Sonic Arts* minor courses for other requirements.

Full-Time Faculty

FREIDA ABTAN, Assistant Professor of Electronic Music Composition - Ph.D., Brown University; Carnegie Mellon, 2021-

CHRISTOPHER ALLEN, Artist Lecturer in Percussion - M.M., Temple University;

ALBERTO ALMARZA, Associate Professor of Flute - M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991-

DONNA AMATO, Artist Lecturer in Piano and Staff Pianist - B.M., University of Arizona; Carnegie Mellon, 1998-

JENNIFER AYLMEYER, Assistant Professor of Voice - M.M., Westminster Choir College;

BRONWYN BANERDT, Artist Lecturer in Chamber Music - M.M., The Juilliard School;

NEAL BERNTSEN, Artist Lecturer in Trumpet - M.M., Northwestern University; Carnegie Mellon, 2003-

JOANNA BOSSE, Interim Head and Visiting Professor - Ph.D., University of Illinois; Carnegie Mellon, 2023-

JEREMY BRANSON, Artist Lecturer in Percussion - M.M., Temple University; Carnegie Mellon, 2009-

WILLIAM CABALLERO, Associate Teaching Professor in Horn - B.M., New England Conservatory; Carnegie Mellon, 2007-

ANDRES CARDENES, Dorothy Richard Starling and Alexander Speyer, Jr. University Professor of Violin Carnegie Mellon, 1989-

ANDREW CARLISLE, Director of Piping

L. MARK CARVER, Associate Teaching Professor in Collaborative Piano - M.M., Carnegie Mellon University; Carnegie Mellon, 1995-

TATJANA CHAMIS, Artist Lecturer in Viola - B.M., Curtis Institute of Music; Carnegie Mellon, 2016-

REBECCA CHERIAN, Artist Lecturer in Trombone - M.M., Yale University; Carnegie Mellon, 1993-

ALEC CHIEN, Artist Lecturer in Piano Literature and Repertoire - D.M.A., The Juilliard School;

FREDERIC CHIU, Assistant Professor of Piano - MM Piano Performance, Juilliard; Carnegie Mellon, 2020-

DENIS COLWELL, Associate Professor - M.M., Carnegie Mellon University; Carnegie Mellon, 1980-

MARIANNE CORNETTI, Artist Lecturer in Voice - BM Voice Performance, Duquesne University; Carnegie Mellon, 2019-

DANIEL CURTIS, Resident Conductor - M.M., Carnegie Mellon University;

MICHELE DE LA REZA, Assistant Teaching Professor of Dance - M.S., University of Pittsburgh; Carnegie Mellon, 2007-

CYNTHIA DEALMEIDA, Associate Teaching Professor in Oboe - M.M., Temple University; Carnegie Mellon, 1991-

JEFF DEE, Artist Lecturer in Bass Trombone - M.M., The Juilliard School; Carnegie Mellon, 2017-

MARK DOMENCIC, Artist Lecturer in Music Theory - M.M., Carnegie Mellon University; Carnegie Mellon, 2007-

THOMAS DOUGLAS, Teaching Professor of Voice - M.M., Duquesne University; Carnegie Mellon, 1991-

JOCELYN DUECK, Assistant Professor of Collaborative Piano - DMA Collaborative Piano, University of Minnesota; Carnegie Mellon, 2017-

PAUL EVANS, Artist Lecturer in Percussion - M.M., Temple University; Carnegie Mellon, 1995-

JAMES FERLA, Artist Lecturer in Guitar - M.F.A., Carnegie Mellon University; Carnegie Mellon, 1977-

NANCY GALBRAITH, Professor of Composition - M.M., West Virginia University; Carnegie Mellon, 1984-

PAUL GERLACH, Artist Lecturer in Music Education - M.F.A., Carnegie Mellon University; Carnegie Mellon, 1982-

NANCY GOERES, Artist Lecturer in Bassoon - B.M., Boston University; Carnegie Mellon, 1988-

SARI GRUBER, Artist Lecturer in Voice - MM Voice, Juilliard School; Carnegie Mellon, 2018-

PETER GUILD, Artist Lecturer in Double Bass - M.M., University of Michigan;

DAVID HARDING, Associate Professor in Viola and Chamber Music - B.M., The Juilliard School; Carnegie Mellon, 2012--

JONATHAN BAILEY HOLLAND, Professor and Jack G. Buncher Head of the School of Music - Ph.D., Harvard University; Carnegie Mellon, 2022-

JAMES HOULIK, Artist Lecturer in Saxophone Eastman School of Music; Carnegie Mellon, 2018-

MICAH HOWARD, Artist Lecturer in Double Bass - M.M., Duquesne University; Carnegie Mellon, 2010-

ANNIE HSIEH, Assistant Teaching Professor of Music Theory University of California, San Diego; Carnegie Mellon, 2018--

ROSEANNA IRWIN, Associate Teaching Professor of Coaching and Accompanying - M.M., Duquesne University; Carnegie Mellon, 1990-

JOHN PAUL ITO, Assistant Professor of Music Theory - Ph.D., Columbia University; Carnegie Mellon, 2011-

PAUL JOHNSTON, Artist Lecturer in Music History - B.M.E., Andrews University; Carnegie Mellon, 2005-

KENNETH KEELING, Associate Head and Professor Emeritus of Music – D.M.A., Catholic University of America; Carnegie Mellon, 1996-

SUNG-IM KIM, Staff Pianist – M.M., Carnegie Mellon University; Carnegie Mellon, 2011-

CRAIG KNOX, Artist Lecturer in Tuba – B.M., Curtis Institute of Music; Carnegie Mellon, 2005-

PETER KOPE, Assistant Teaching Professor of Dance University of Dayton; Carnegie Mellon, 2007-

STEPHEN KOSTYNIK, Artist Lecturer in French Horn – B.M., The Juilliard School; Carnegie Mellon, 2008-

JASON KUSH, Artist Lecturer in Saxophone – D.M.A., University of Miami; Carnegie Mellon, 2017-

LANCE LADUKE, Artist Lecturer in Euphonium – B.M., Michigan State University; Carnegie Mellon, 2003-

CARLA LARocca, Associate Teaching Professor of Keyboard Studies – M.F.A., Carnegie Mellon University; Carnegie Mellon, 1991-

ELIZABETH LAWRENCE, Artist Lecturer in Jazz Voice and Director of Jazz Vocal Ensemble – M.M., Manhattan School of Music; Carnegie Mellon, 1996-

CHRISTOPHER LYNCH, Artist Lecturer in Music History – Ph.D., University of Buffalo; Carnegie Mellon, 2018-

LUZ MANRIQUEZ, Associate Teaching Professor in Collaborative Piano – M.M., Carnegie Mellon University; Carnegie Mellon, 1992-

JOHN MARCINIZYN, Artist Lecturer in Guitar and Composition – Ph.D., University of Pittsburgh; Carnegie Mellon, 1991-

LORNA MCGHEE, Artist Lecturer in Flute Royal Scottish Academy of Music and Drama; Carnegie Mellon, 2015-

MONIQUE MEAD, Director of Music Entrepreneurial Studies – M.M., Indiana University-Bloomington; Carnegie Mellon, 2012-

ANNE MOSKAL, Artist Lecturer in Solfege – M.M., Carnegie Mellon University; Carnegie Mellon, 2011-

STEPHEN NEELY, Artist Lecturer in Eurhythmics – M.M., Carnegie Mellon University; Carnegie Mellon, 1998-

RODRIGO OJEDA, Staff Pianist – M.M., Carnegie Mellon University; Carnegie Mellon, 2011-

BENJAMIN OPIE, Artist Lecturer in Music Technology – M.M., Duquesne University; Carnegie Mellon, 2005-

NATALIE OZEAS, Professor of Music Education – Ed.D., University of Pittsburgh; Carnegie Mellon, 1989-

DIMITRI PAPADIMITRIOU, Artist Lecturer in Chamber Music – D.M.A., Royal Irish Academy of Music; Carnegie Mellon, 2015-

DAVID PREMO, Artist Lecturer in Cello – M.M., Indiana University; Carnegie Mellon, 1994-

RYAN PRENDERGAST, Assistant Teaching Professor – Ph.D., University of Illinois; Carnegie Mellon, 2022-

KATHERINE PUKINSKIS, Assistant Professor of Composition and Theory – Ph.D., University of Chicago; Carnegie Mellon, 2022-

RICHARD RANDALL, Assistant Professor of Music Theory – Ph.D., Eastman School of Music; Carnegie Mellon, 2008-

SUSAN RAPONI, Assistant Professor of Music – PhD Music Education, University of Toronto; Carnegie Mellon, 2019-

MICHAEL RUSINEK, Artist Lecturer in Clarinet – M.M., Curtis Institute of Music; Carnegie Mellon, 1998-

VAHAN SARGSYAN, Staff Pianist – M.M., Yerevan Komitas State Conservatoire;

SERGEY SCHEPKIN, Associate Professor of Piano – D.M.A., New England Conservatory; Carnegie Mellon, 2003-

STEPHEN SCHULTZ, Associate Teaching Professor of Music History and Flute – M.M., San Francisco State University; Carnegie Mellon, 2002-

RICCARDO SCHULZ, Associate Teaching Professor and Director of Recording Activities – M.A., University of Pittsburgh; Carnegie Mellon, 1988-

FRANCO SCIANNAMEO, Associate Teaching Professor of Film Musicology and CFA Associate Dean – D.M., Conservatorio di Musica, Santa Cecilia;

MARIA SPACAGNA, Associate Professor of Voice – M.M., New England Conservatory; Carnegie Mellon, 2012--

JESSE STILES, Assistant Teaching Professor of Sound Media – M.F.A., Rensselaer Polytechnic Institute; Carnegie Mellon, 2015-

STEPHEN STORY, Associate Conductor of Wind Ensemble – M.M., Carnegie Mellon University;

PETER SULLIVAN, Artist Lecturer in Trombone Aspen School of Music; Carnegie Mellon, 2000-

DANIEL TEADT, Artist Lecturer in Voice – M.M., University of Illinois; Carnegie Mellon, 2011--

THOMAS THOMPSON, Associate Teaching Professor of Clarinet and Co-Director of Wind Ensemble – M.M., Northwestern University; Carnegie Mellon, 1986-

KELLY TRUMBULL, Artist Lecturer in Acting – M.A., New York University; Carnegie Mellon, 2015-

WILLIAM VAN DER SLOOT, Assistant Teaching Professor of Violin – Diploma, International Institute for Chamber Music; Carnegie Mellon, 2017-

GRETCHEN VAN HOESEN, Artist Lecturer in Harp – M.M., The Juilliard School; Carnegie Mellon, 1985-

GEORGE VOSBURGH, Artist Lecturer in Trumpet and Co-Director of Wind Ensemble – B.A., University of Rochester; Carnegie Mellon, 2003-

JAMES WHIPPLE, Artist Lecturer in Music Theory – B.A., Carnegie Mellon University; Carnegie Mellon, 1995-

ANNE MARTINDALE WILLIAMS, Artist Lecturer in Cello – Diploma, Curtis Institute of Music; Carnegie Mellon, 1987-

ALEXA WOLOSHYN, Assistant Professor of Musicology – Ph.D., University of Toronto; Carnegie Mellon, 2016--

CHRISTOPHER WU, Artist Lecturer in Violin – B.A., Eastman School of Music; Carnegie Mellon, 2009-

LENNY YOUNG, Artist Lecturer in Solfege – M.M., Carnegie Mellon University; Carnegie Mellon, 2015-

MONICA YUNUS, Artist Lecturer in Voice Entrepreneurship – M.M., The Juilliard School; Carnegie Mellon, 2018-

School of Music Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

57-008 Vocal Master Class II

Fall

This is a group coaching class for sophomore voice majors.

57-009 Vocal Master Class II

Fall and Spring

This is a group coaching class for sophomore voice majors.

57-010 Voice Studio Performance Class

Fall and Spring: 1 unit

Vocal Studio Performance Class is a required class for both undergraduate and graduate voice majors. Each student must participate in two singing rotations each semester and will receive written comments from the voice faculty. Students are also required to attend four studio classes each semester. Grading is pass/fail based on attendance.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-015 Violin Studio Performance Class

Fall and Spring

Once a week throughout the semester a "violin studio performance class" takes place. A studio class is a most important performance opportunity as it is a step between the studio lessons and the concert stage. Students perform the repertoire they are working on in front of the class and Prof. Forough. Along with comments from the class, Prof. Forough works one on one with each student. The repertoire performed can be solo pieces or accompanied pieces. This class is for violin majors who are studying with Prof. Forough. Other students may audit the class.

57-016 Viola Studio Performance Class

Fall and Spring

TBA

57-018 Double Bass Studio Performance Class

Fall and Spring

TBA

57-020 Flute Studio Performance Class

Fall and Spring

TBA

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-021 Oboe Studio Performance Class

Fall and Spring

TBA

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-022 Clarinet Studio Performance Class

Fall and Spring

The purpose of this class is to have performance before an audience (studio class members) to ease performance anxiety. The class meets once a week, is not for credit and is not mandatory. In addition to playing, the class listens to recordings of various styles of clarinet playing.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-023 Bassoon Studio Performance Class

Fall and Spring

TBA

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-028 Euphonium Studio Performance Class

Fall and Spring

tba

57-030 Percussion Studio Performance Class

Fall and Spring

TBA

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-036 Vocal Master Class

Fall

TBA

57-037 Vocal Master Class

Spring

TBA

57-038 Vocal Master Class I

Fall

TBA

57-039 Vocal Master Class II

Spring

TBA

57-100 Convocation

Fall and Spring: 1 unit

A weekly meeting for all music students that features lectures, concerts, and other presentations related to professional development.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-101 Introduction to Music Technology

Fall and Spring: 6 units

This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-102 Finale

Spring: 6 units

This course provides hands-on and in-depth instruction of the Finale music notation program by Coda Music Software. Students will learn how to efficiently use the various notation tools that Finale has to input, edit, and manipulate music. MIDI input, playback, and transcription will also be covered to allow students to quickly notate and hear their music. The goal is to create professional-looking printed scores and parts in a variety of styles from Classical to Contemporary. Open to music majors only except by instructor permission. Introduction to Music Technology (57801/871) or equivalent experience required.

Prerequisites: 57-171 or 57-101

57-103 Elective Studio (Beginning Piano Class)

Fall and Spring: 3 units

TBA

57-109 Elective Studio (Guitar Class)

Fall and Spring: 3 units

Using classical and jazz guitar methods, this course is designed to provide a basic set of techniques that will allow students to pursue the avenue of guitar playing that most interests them. While emphasis will be on developing skills in playing the guitar, a basic understanding of the principles of music theory as applied to the guitar will also be acquired. While few students will find it possible to master all of the materials presented, an exposure to the many possibilities of musical expression available on the guitar and an understanding of basic music theory will help to broaden the students' perspective and make future musical experiences, such as listening and performing, more rewarding. Each student is expected to have his/her own instrument. A guitar in good working condition is essential. An acoustic classical or steel string is preferred, an electric with a small battery operated amp is acceptable. Students having no previous training on the guitar will find this class most valuable.

57-110 Elective Studio (Voice Class)

Fall and Spring: 3 units

Students enrolled in group voice will gain an understanding of basic vocal technique and a variety of singing styles. Students will learn about proper breathing, tone production and posture. Vocal styles will include pop, jazz, musical theater and classical. Students will also explore harmonization, improvisation and audition techniques for the singer. This class is geared towards the beginning student.

57-111 Movement and Dance I

Fall: 3 units

The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2/>)

57-112 Movement and Dance II

Spring: 3 units

The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance.
Prerequisite: 57-111

57-149 Basic Harmony I

Fall: 9 units

This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-150 Basic Harmony II

Fall: 9 units

This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. It includes work on fundamentals for inexperienced students.

Prerequisite: 57-149

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-151 Counterpoint in Theory and Application

Fall: 6 units

In Counterpoint in Theory and Application, students begin by learning the traditional five species of counterpoint in a tonal context. They then build on this foundation, learning to analyze music in terms of the underlying counterpoint and to apply this analysis to performance, and producing original tonal compositions in two voices.

Prerequisites: 57-153 or 57-150

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/CTP/CTPMain.html

57-152 Harmony I

Fall: 9 units

This course deals with common-practice harmony. It includes triads and their inversions, tonality and modality, non-harmonic tones, cadences, and the basic concepts of modulation. Section assignment is determined by a placement test.

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-153 Harmony II

Spring: 9 units

This course is a continuation of the study of common practice harmony, exploring dissonant and chromatic harmony.

Prerequisite: 57-152

Course Website: https://www.andrew.cmu.edu/user/johnito/music_theory/harmony1and2/HarmMain.html

57-161 Eurhythmics I

Fall: 3 units

Dalcroze Eurhythmics is a unique approach to music learning based on the recognition that meaningful rhythmic movement experience, associated with ear-training and improvisation, reinforces understanding of music concepts, enhances musicianship, and focuses awareness on the physical demands of artistic performance. All concepts are experienced in a musical context. Rhythm reading, notation, analysis, and improvisation are integral to the course. Eurhythmics I covers basic binary and ternary metric units and rhythm patterns in relation to these metric units within simple and compound meters.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2/>)

57-162 Eurhythmics II

Spring: 3 units

Eurhythmics II introduces combinations of binary and ternary metric units, mixed meters, changing meters, and notation and performance of cross-rhythms.

Prerequisite: 57-161

57-163 Eurhythmics III

Fall: 3 units

Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). Dalcroze discovered that meaningful rhythmic movement experiences away from their instrument allows students to focus awareness on the physical demands of artistic performance while demonstrating knowledge and understanding of the expressive/interpretive as well as the theoretical aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics III Course Content: Divisive vs Additive rhythm, Metric transformation, Irregular subdivisions of metric units, Cross rhythms of 3 against 4, 3 against 5, 4 against 5.
Prerequisite: 57-162

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2liizk2/>)

57-164 Eurhythmics IV

Spring: 3 units

Eurhythmics is a unique approach to music learning developed by the Swiss composer and educator Emile Jaques-Dalcroze (1865-1950). It is a process for awakening, developing and refining innate musicality through rhythmic movement, ear training and improvisation. Through rhythmic movement, students demonstrate knowledge and understanding of the expressive/interpretive as well as the metrical/structural aspects of music. Sight reading, conducting, notation, analysis and improvisation are integral to the course. Eurhythmics IV Course Content: More complex rhythmic problems encountered in composed music, Changing meters and changing metric units within a composition, Rhythm reading of patterns using small note values, Messiaen rhythm techniques.

Prerequisite: 57-163

57-171 Introduction to Music Technology (self-paced)

Fall and Spring: 6 units

This course gives an overview of music technology through practical information and several hands-on projects. Concepts such as MIDI and digital audio are introduced and specific topics are covered in detail including sequencing, music notation, digital recording, mixing, and production. Throughout the course, students are required to complete several projects and create musical compositions in styles of their own choosing. The student is not graded on the "musicality" of these compositions, but instead on how well they meet the stated project goals by correctly using specific equipment and/or computer programs. This is a self-paced version of 57-101. Material will be covered during weekly class sessions, though students are expected to make time in the evenings or weekends to work on their projects in either the MTC (MM119A) or some other cluster. Students with prior experience may pass out of certain classes and projects by providing teacher with equivalent work (pending teacher approval). In addition to the required projects, there is a final exam which is administered during the last class session.

57-173 Survey of Western Music History

Fall and Summer: 9 units

This course surveys the development and contexts of European art music and its global adaptation. While keeping in view the chronology from Gregorian chant to the present, this survey emphasizes key personalities and issues, particularly issues relating to period style and interpretive decisions in performance.

Course Website: https://cmu.app.box.com/files/1/f/9350209729/1/f_33705395781 (https://cmu.app.box.com/files/1/f/9350209729/1/f_33705395781/)

57-180 Basic Solfege I

Fall: 3 units

This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes work on fundamentals for inexperienced students.

57-181 Solfege I

Fall: 3 units

This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-182 Solfege II

Spring: 3 units

Continues 57-181 Solfege I.

Prerequisites: 57-181 or 57-180

57-183 Solfege III

Fall: 3 units

Continues 57-182 Solfege II. Students are given assignments of classical music written in the treble, bass, soprano, alto, and tenor clefs. Writing consists of two-part contrapuntal dictations.

Prerequisite: 57-182

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-184 Solfege IV

Spring: 3 units

Continues 57-183 Solfege III. Students learn to read atonal music and practice three-part contrapuntal dictations as well as harmonic dictations. Prerequisite: 57-183

57-185 Advanced Solfege I

Fall: 3 units

This course improves the student's ability to analyze music aurally and to sing at sight in traditional meters and tonalities using the "fixed do" system. Solfege is the integration of the three cognitive skills: reading music, hearing music, and writing what one hears. Section assignment is determined by a placement test. It includes advanced work for experienced students and those with perfect pitch.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285566497 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285566497/)

57-186 Advanced Solfege II

Spring: 3 units

Continues 57-185 Advanced Solfege I.

Prerequisite: 57-185

57-188 Repertoire and Listening for Musicians

Fall: 1 unit

This course is the required listening component for Survey of Western Music History (57-173). In this course, students listen critically to essential music which has stood the test of time and to superior performances. It features 2-3 hours of listening per week.

57-189 Introduction to Repertoire and Listening for Musicians

Fall: 3 units

One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for freshman music majors.

57-190 Repertoire and Listening for Musicians I

Spring: 3 units

One of the most important ways of achieving musical excellence is to listen. In this course, students listen critically to essential music which has stood the test of time and to superior performances. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. This semester introduces full scores for chamber and orchestral music. Midterm and final listening tests. This course contains midterm and final listening tests. Proficiency requirement for freshman music majors. Other students admitted with instructor's permission.

57-191 Keyboard Studies

Fall and Spring: 3 units

All undergraduate music students are required to take four semesters of keyboard studies during their freshman and sophomore years. The emphasis of this course is to develop a practical keyboard facility, which includes keyboard theory and technique, sightreading, solo and ensemble repertoire, transposition, and a variety of creative activities such as harmonization and improvisation.

57-196 Collaborative Piano Skills I

Fall: 3 units

A required course for first year piano majors. The skills include sightreading, basic keyboard harmony, transposition, and improvised accompaniments for popular or musical theater songs from either a piano reduction or a lead sheet. The students participate in collaborative situations such as juries, recitals, and class presentations. The presentations are critiqued by the instructor and by other students.

57-207 Music Studio

Fall

Provides the opportunity for students to pursue study in a second instrument or area. By special permission only.

57-208 Music Studio

Spring

Provides the opportunity for students to pursue study in a secondary instrument or area. By special permission only.

57-209 The Beatles

Intermittent: 9 units

This course will focus on the phenomenon of the Beatles. Their songs will be studied, with analysis of the musical and lyrical content and structural elements. What musical styles do the songs address? What were their musical influences? In what ways did their music change over the years? Also, the music's social context will be studied. Why were the Beatles so popular and influential? What exactly caused Beatlemania? How did the group form, grow, and end? The Beatles are the most famous rock group in history; the reasons for this are as much cultural as musical, and we'll study the two elements simultaneously. Open to all undergraduate students.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1_f_106285571361 (https://cmu.app.box.com/files/0/f/11681158556/1_f_106285571361/)

57-210 The Beatles

Intermittent: 3 units

TBA

57-211 Movement and Dance III

Fall: 3 units

The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance. Prerequisite: 57-112

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-212 Movement and Dance IV

Spring: 3 units

The CMU School of Music movement curriculum is designed to expose students to various styles and genres of contemporary and traditional forms of dance and movement. Students will increase their technical proficiency and personal artistry in dance in order to expand their physical skills as vocal performance artists. Courses will: Improve students' posture and strength, Increase proficiency in dance vocabulary, Increase ability to recognize, interpret and execute choreography, movement and staging direction, Enhance kinesthetic awareness and physical confidence and Improve overall health. With a focus on creativity and expression in movement, these courses concentrate on using the body as a tool in the creative process. Throughout "Movement and Dance I - IV", courses will include movement fundamentals, modern dance, ballet, partnering, dance composition/improvisation; as well as mini-courses in dance forms which can include stage combat, Flamenco dance, pilates and ballroom dance. Prerequisite: 57-211

57-220 English Diction

Fall: 3 units

This one semester course helps singers sing English songs from the Classical and Musical Theater repertoire with clarity, accuracy, ease, uniformity, and expressiveness; to illuminate meaning; and to improve tonal quality through diction.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-221 Italian Diction

Fall: 3 units

A study of the fundamentals of Italian diction and development of legato vocal style through the analysis of grammatical usage, word construction, vowel colorization, and consonant articulation. Included are in-class performance evaluations, listening assignments, critiques, and private coachings.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-222 French Diction

Fall: 3 units

This course is designed primarily for singers specializing in French Art Songs of the 19th and 20th centuries. It deals with the use of the International Phonetic Alphabet, its application to singing in French, the use of the liaison and the preparation of the text of a song or aria. One-third of the course is theory and two-thirds of the course is spent on application by performance with piano accompaniment.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-223 German Diction

Fall: 3 units

In-depth study of German diction - development of legato vocal style in German through the analysis of grammatical usage, word construction, vowel colorization and consonant articulation. Included are in-class German diction evaluations, peer assessment, and emphasis on competency in using the International Phonetic Alphabet.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-227 Jazz Instrumental Ensemble

Fall and Spring: 3 units

This ensemble incorporates a comprehensive approach to Big Band performance and study. The music performed is drawn from all eras of big band repertoire with occasional programs of specific composers and genres. The ensemble is carefully coordinated with the Jazz Vocal Ensemble and major ensembles in order to challenge and prepare students for professional music career opportunities. The ensemble performs on the regular School of Music concert series (2-3 shows per semester) and for on-campus events. Admission of undergraduate and graduate students is by competitive audition and placement is by the director. Grading is based on attendance, preparation, and consistent progress. Prerequisite: 57-227

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-228 Chamber Music: Woodwind and Mixed

Fall: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-229 Chamber Music: Woodwind and Mixed

Fall and Spring: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-230 Baroque Ensemble

Fall and Spring: 3 units

Carnegie Mellon Baroque is a performing ensemble of 15-25 players consisting of winds, strings and keyboard. Students in this ensemble explore the orchestral and chamber music of the 18th Century. The Ensemble performs on modern instruments, incorporating performance practice ideals of the Baroque era. Throughout the rehearsal process, students are encouraged to study original source materials and arrive at historically informed and musically satisfying performances.

57-231 Chamber Ensemble

Intermittent: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. Low Brass Ensemble: The low brass ensemble pushes the boundaries of what is "supposed" to be played by an ensemble of this type. Players will be involved in the programming, arranging and planning of performances and will learn valuable musical, creative, promotional and organizational skills.

57-232 Chamber Music: Guitar

Fall and Spring: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-233 Sonatas

Fall and Spring: 3 units

This course focuses on coaching of performance groups with two members. It parallels Chamber Music, which focuses on coaching of performance groups with three or more members.

57-234 Performance for Composers

Fall: 3 units

This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the fall semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only.

57-236 Performance for Composers

Spring: 3 units

This course is for composition majors who choose to fulfill the performance elective requirement in the junior year by completing an independent performance project in the spring semester. Examples of projects can include producing a recital of his/her compositions, or pursuing other performing interests, such as writing music for a School of Drama production. Registration by composition faculty permission only. Prerequisite: 57-234

57-240 Acting I

Fall: 3 units

The basics of acting will be established throughout the first year following the guideposts described in *Audition*, by Michael Shurtleff and #237;s. Structured improvisations, monologues, scene work, songs, and arias will provide a platform for the development of stage presence and effective communication. Each semester will finish with a group project that provides an opportunity for the students to begin to work together as a cast.

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1_f_106285564193
(https://cmu.app.box.com/files/0/f/11681158556/1_f_106285564193/)

57-241 Acting II

Spring: 3 units

Continues 57-240 Acting I.

Prerequisite: 57-240

57-257 Orchestration I

Fall: 6 units

This is an introductory course for all music majors and required for sophomore composition majors. The characteristics of each instrument of the orchestra are studied thoroughly. Orchestral textures from the classics to contemporary music are studied and analyzed. Prerequisites: 57-156 or 57-150 or 57-153

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-258 20th-21st Century Techniques

Spring: 6 units

This course is open to all music majors and required for sophomore composition majors. The most important techniques from Debussy to the present will be reviewed in terms of melody, harmony, and form. Tonality, serialism, and aleatoric devices will be studied. Compositional techniques of the 20th Century are put into perspective and compared with other developments in the arts. The class is conducted as an open forum in which discussions are encouraged.

Prerequisite: 57-151

57-271 Orchestration II

Fall: 6 units

Students will analyze music from the Classical to Avant-Garde and use the knowledge acquired to orchestrate piano scores in the appropriate style. Style, practicality, color, and imagination are encouraged. This course is designed for junior composition majors. Other students may register with instructor permission after an interview.

Prerequisite: 57-257

57-273 Piano Pedagogy I

Fall: 6 units

This course offers an historical overview of piano pedagogy including its significant developments over the past forty years. Topics covered include beginning piano techniques, the sequencing of concepts and materials, common problems among beginning pianists, practicing, motivation, and parental involvement. Current representative beginning piano methods will be surveyed.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-274 Piano Pedagogy II

Spring: 6 units

Beyond the beginning years: this course covers piano pedagogy of intermediate and early advanced level students. Topics include "What is a good piece?" Standard literature and technical development repertoire lists will be studied. The business of piano teaching and the instruction of college keyboard skills for non-piano majors will be discussed.

Prerequisite: 57-273

57-275 Piano Pedagogy III

Fall: 6 units

Continuation of 57-274. Intermediate literature, analysis, teaching, and performance will be covered. Topics include "What is style?"

Prerequisite: 57-274

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-276 Piano Pedagogy IV

Spring: 6 units

Continuation of 57-275. Early advanced literature, analysis, teaching, and performance will be covered.

Prerequisite: 57-275

57-283 Music History I

Fall: 9 units

This class will be an in-depth analytical study of music of the Medieval, Renaissance, and Baroque Periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style and to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.

57-284 Music History II

Spring: 9 units

This class will be an in-depth analytical study of music of the Classical and Romantic periods. It will emphasize selected genres and forms by representative composers in order to trace the evolution of musical style, to clarify the main characteristics of these periods, to set the musical developments in broader cultural contexts, and to apply this knowledge to practical decisions made by today's musician.

Prerequisite: 57-283

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-285 Music History III

Spring: 9 units

This class will be an in-depth analytical study of music from the 20th and 21st centuries. It will emphasize selected genres and approaches by representative composers in order to trace the various threads of musical style, to clarify the main characteristics of the period's music, to set the musical developments in broader cultural contexts, and to apply this knowledge to the lives and musical practices of musicians today.

Prerequisites: 57-283 and 57-284

57-289 Repertoire and Listening for Musicians II

Fall: 3 units

This is a continuation of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. This semester's repertoire includes units focusing on contrapuntal masterpieces from the Middle Ages through 20th Century, and further builds score-reading experience. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I and II are not prerequisites.

57-290 Repertoire and Listening for Musicians III

Spring: 3 units

This is the culmination of the School of Music's four-semester listening curriculum. Students listen critically to essential music which has stood the test of time and to superior performances. Highlights of this semester's repertoire include units on Middle and Late Beethoven as well as a decade-by-decade survey of the 20th Century. This on-line course features listening and discussion in a virtual coffee shop atmosphere. 2-3 hours of listening per week. Midterm and final listening tests. Proficiency requirement for sophomore music majors. Other students admitted with instructor's permission. Repertoire and Listening for Musicians I-III are not prerequisites.

57-293 Keyboard Studies Test (Degree)

Fall and Spring

This is the keyboard proficiency test which is a requirement for all undergraduate music majors who are not piano majors.

57-294 Beginning Piano Test

Fall and Spring

This is the keyboard proficiency test which is a requirement for all music performance, music composition, music technology, and music theory minors.

57-300 Advanced Bagpipe and Drum Band

Fall and Spring: 6 units

The Pipe Band at Carnegie Mellon is a competitive Grade 3 band in the Eastern United States Pipe Band Association. The band competes at various Scottish festivals and Highland Games during the school year. The band also performs at university activities throughout the year. These include Convocation, Homecoming, Spring Carnival, and Commencement. Other engagements are Spring Concert at CMU and the St. Patrick's Day Parade in Pittsburgh. The band has also played as an opening act for the Pittsburgh Steelers and a Rod Stewart concert.

Prerequisite: 57-299

57-301 Bagpipe History

Intermittent: 3 units

This course covers all types of bagpipe music, including Ceol Mor and Ceol Beag, and studies the prominent composers from MacCrimmon to the present day. Students compose their own material in all time signatures commonly used. The course covers Piobaireachd, Marches, Strathspeys, Reels, Hornpipes, and jigs, as well as harmony and the ability to write out tunes from repetitive listening.

57-303 Bagpipe Literature and Repertoire

Intermittent: 3 units

This course will cover the origins of the bagpipe and Piobaireachd, bagpipe music in competition, military, and dance. We will also cover major piping competitions, famous bagpipe players, and piping today.

57-304 Bagpipe Maintenance

Intermittent: 3 units

All aspects of bagpipe maintenance are covered in this course, from basic hemping and tying in bags to reeds set-up and manipulation. The course includes study of all types of reeds, cane and synthetic, as well as drone and chanter, and recognition of pipemakers' patterns and distinctive hallmarks.

57-305 Bagpipe Reedmaking

Intermittent: 3 units

This is a hands-on course where the student learns how to make pipe chanter reeds by the traditional method of gouging, shaping, and tying up. This course follows 57-304, Bagpipe Maintenance. Further analysis of chanter and drone reeds will be covered also.

Prerequisite: 57-304

57-306 World Music

Fall: 9 units

A study of major musical traditions from around the world, including classical music from Asia (broadly defined) and the Middle East, as well as traditional musics in Africa, Europe, and the Americas. This course will examine music in its socio-cultural context, and will demonstrate how learning about music from diverse cultures increases cross-cultural understanding. This course will engage with readings, listening examples, multi-media presentations, in-class discussions, music-making activities, and special guests (virtual and in person).

57-307 Bagpipe Theory

Intermittent: 3 units

This course prepares students for 57-302, Bagpipe Construction. All aspects of Bagpipe Theory are covered, including time signatures, grand staff, musical rudiments, musical terms and definitions, and writing of simple tunes from memory.

57-313 Topics in Movement and Dance: Techniques

Fall: 3 units

This intermediate level course furthers the dance foundation practiced in the first two years of the School of Music movement curriculum. This modern dance technique class will explore momentum based phrase material, body alignment and release, movement dynamics, inversions and floor work. This course focuses on the information and the tools needed to extend movement technique, skills, and performance quality.

Prerequisite: 57-212

57-314 Topics in Movement and Dance: Movement Lab

Spring: 3 units

This intermediate level course will encourage an understanding of dance through the practice of creative improvisation and composition. The course is designed to develop the process of exploration and creation of movement and its performance applications.

Prerequisite: 57-212

57-329 Beginning Piano for Minors

Fall and Spring: 3 units

This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-330 Beginning Piano for Minors

Spring: 3 units

This is a small group lesson for music performance, music composition, music technology, and music theory minors who cannot pass the required beginning piano test.

57-331 Principles of Education

Fall: 9 units

This course introduces students to the art and science of being an educator. Content includes views of the academic and social structure of the school, physiological and amp; social characteristics of learners that influence instruction, widely recognized research on learning and amp; teaching, and appropriate and amp; effective class preparation and teaching strategies.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>)

57-332 Introduction to Conducting

Fall: 6 units

This course develops the basic skills needed to conduct instrumental ensembles or a small orchestra. It is primarily focused on conducting technique, body language and body coordination and communication. It also deals with learning and translating an instrumental or orchestral score into actual music. The goal is to achieve a clear and communicative technique upon which an artistic interpretation can be built. The student works periodically with a pianist or a small chamber ensemble.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>)

57-333 Band and Choral Arranging

Spring: 6 units

The main purpose of the course is to enable students to compose arrangements suitable for public performance for a cappella choir, instrumental chamber groups, and concert band. By the end of the course, students should achieve a satisfactory level of competence in regard to: 1. Effective writing through knowledge of instrumental and vocal performance techniques. 2. Writing homophonic, polyphonic, homorhythmic and monophonic textures for effective ensemble sound and variation. 3. Identifying and creating effective orchestration for instrumental and vocal ensembles. 4. Identifying expected music knowledge, performance ability, and attitudes of middle and high school music ensemble students.

Prerequisites: 57-153 or 57-150

57-334 Fundamentals of Marching Band

Fall: 3 units

A marching band, due to its visibility and high degree of student involvement, is an integral part of secondary school music programs. The well-schooled music education graduate must have knowledge of this unique form of music performance. This course, designed primarily for those seeking a career in teaching, will accommodate students with no experience and others who have participated in marching band. Among the many areas of concentration will be: philosophy, show charting, marching fundamentals and commands, logistical awareness, and budget formulation. Observation of and active assistance with Carnegie Mellon Kiltie Band will be part of the course content.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2liizk2>)

57-336 Instrumental/Choral Conducting

Spring: 6 units

This course is a continuation of Introduction to Conducting. The course offers a more detailed conducting technique, adding those subjects related to choral conducting. This is followed by the study and the analysis of interpretation from the point of view of the conductor and ends stressing a set of important practical items, including the psychological attitude and the leadership a conductor must develop as well as the organization and achievement of a fruitful rehearsal technique. The students work periodically with a pianist, a soloist or a chamber ensemble on traditional works and on their own compositions in the case of composition majors.

Prerequisite: 57-332

57-337 Sound Recording

Fall and Spring: 6 units

Sound Recording is the first (and required) course in the sequence that includes Sound Editing and amp; Mastering and Multitrack Recording. Sound Recording centers around the Vlahakis Recording Studio in the College of Fine Arts: how the studio works, and how to record various types of music. The method of instruction is to learn by doing, and the goal is to achieve professional-sounding results. Equipment includes a complete 24-track Pro-Tools system, professionally designed control room that can accommodate up to 24 people, outboard preamps and other gear, and an interesting array of microphones. All recording is direct to hard disc. Grading is based on recording projects, class attendance, mastering studio hardware and software, and several quizzes. Work outside of class requires about 3 to 5 hours a week to complete projects and take-home quizzes.

57-338 Sound Editing and Mastering

Fall and Spring: 6 units

The raw recording is just the first step in the process of creating a professional finished audio product. "Editing" is the art of piecing together different takes to make one final 'good take.' "Mastering" is the art of polishing the 'good take' to perfection and #8212;balancing all the instruments and tracks, adding special effects, setting final levels. If 'recording' seems like an high-energy activity and #8212;involving engineers, musicians, producers and #8212;'editing and mastering' are the necessary counterparts and #8212;long tedious hours of solitary confinement honing the skills of the mastering engineer. Those taking this course are expected to have significant music skills: actively playing a musical instrument (or composition), and/or the ability to read a piano score at the least, and a full orchestra score from any recent century, including our own, at the most. Class attendance is essential; work outside of class is necessary.

Prerequisites: 57-342 or 57-337 or 57-341 or 57-651

57-339 Acting III

Fall: 6 units

This course will build upon the foundation laid in the first year, with a more concentrated look at scene work, an audition workshop that focuses on cold readings as well as monologues, and a character-development project that works to identify specific issues that inhibit freedom on stage. More in-depth work on songs and arias will lead into a musical scene project. The semester will close with a classical text project in which the students will work with verse.

Prerequisite: 57-241

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564705 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285564705/)

57-340 Acting IV

Spring: 6 units

Continues 57-339 Acting III.

Prerequisite: 57-339

57-343 Music, Technology, and Culture

Intermittent: 9 units

Music has been a part of our individual and communal lives for 40,000 years. We developed the technology to record and playback music for about 140-years ago. In this seminar we will study the relationship of music, technology and culture from a variety of disciplinary approaches including science and technology studies, musicology and ethnomusicology, neuroscience, sound studies, critical race and ethnicity studies, political economy, cultural studies and media archeology. The course will focus on the impact mediating technologies like vinyl, cassette tapes, mp3s, film and television, the development of music journalism and of course live human performance have had on our social, political and personal interactions with music. We have built the course around case studies that illustrate the intersection of music, technology and culture such as audio analgesia devices, movie soundtracks, streaming services, the rise of internet "listicles" and other crucial moments in twentieth and twenty-first century musical culture. Students in this course will develop critical projects that cross technological, humanistic, and musical boundaries. We hope that students come away from this class with better a host of critical tools to better think about what music means to us and how mediating technologies redefine these meanings.

57-344 Experimental Sound Synthesis

Intermittent: 9 units

This is a course that will guide students into the world of experimental approaches to music and sound production, with particular emphasis in some of the key practices and concepts developed in the 20th and 21st centuries. We will examine a variety of ways in which sound works are made and perceived; understanding the historical perspectives and critical viewpoints of each approach through the application of hands-on practicum. The topics covered in the course are divided into three large areas: the art of sound, the use of technology in the production of sound works, and the creation of interdisciplinary sound installation. Students from different disciplines will work together to collaborate on the designing, prototyping and execution of a series of ambitious projects in response to the topics covered in class.

57-345 Hacking the Music World

Fall and Spring: 9 units

In this course we will perform a series of real-world experiments that examine new models for music creation, promotion, and distribution. We will produce original music videos, explore social media marketing and amp; optimization, examine new platforms for monetization, and officially release digital albums and apps. The proliferation of digital music distribution has revolutionized how music is experienced in the 21st century. Technologies for music listening, music sharing, and music discovery are in a state of rapid and limitless evolution. There is no longer a single model for a rewarding life in the world of music ? we must learn to adapt to the constantly evolving landscape of the 21st century. We must hack the music world! While examining new approaches to distribution and publication, we will also explore the question of how electronic media is redefining our understanding of music-making itself. Does a new album necessarily need to be a fixed set of sound recordings? What if it was a mobile app that reacts to the listener's environment? What if our new album used mutating algorithms to generate new musical experiences every time the listener hits play? Throughout the semester we will form teams combining musicians, software programmers, artists, and entrepreneurs. Our teams will work together to produce new music, to design new music distribution methodologies, and to perform social media experiments that enhance the visibility of our work. Students participating in the course should have proficiency in one or more of the following areas: Social Media Optimization, Music Recording or Video Production, Leveraging Web Application APIs, Mobile Application Design and amp; Implementation. Prerequisites are the IDEATe portal courses or permission of the instructor. Please note that there will be a lab usage fee associated with this course.

Prerequisites: 18-090 or 16-223 or 60-223 or 62-150 or 15-104

57-347 Electronic and Computer Music

Fall: 6 units

This course builds on the concepts learned in Introduction to Music Technology (57-101) and gives added knowledge in the areas of composition using digital and analog devices as well as various computer programs. Building computer models of both analog and digital synthesizers as well as drum machines, loop players and various other sound processing effects will be covered in detail. Students will be required to produce several projects throughout the course demonstrating their understanding of various concepts in electronic music. More emphasis is placed on the overall quality of the end musical product than in 57-101 in order to prepare students for music production in a professional setting.

Prerequisites: 57-101 or 57-171

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-349 Supervised Theory Teaching

Fall and Spring: 6 units

This course provides teaching skills in theory for students who have already completed the theory program at Carnegie Mellon University or who have demonstrated theory competence. The students will attend all sessions of the assigned theory class and will assist the professor by correcting homework, delivering a short lecture, developing a class syllabus and tutoring individual students. The work is done under direct supervision and advice from the regular professor who is always present in the class. Enrollment limited to a maximum of two students per class.

57-350 Strauss Wind Serenade

Fall and Spring: 3 units

TBA

57-351 Dalcroze Piano Improvisation

Fall and Spring

These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.

Prerequisite: 57-350

57-352 Dalcroze Piano Improvisation

Fall and Spring

These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.

Prerequisite: 57-351

57-353 Dalcroze Piano Improvisation

Fall and Spring

These courses are required for candidates in the Dalcroze Certification program. They are designed to develop keyboard improvisation skills necessary for teaching Eurhythmics.

Prerequisite: 57-352

57-355 Secondary Guided Teaching

Spring: 3 units

This course enables students to apply instructional strategies in local secondary school music classes. School visits provide opportunities to work with band, choral, and amp; orchestral ensembles and general music classes. Seminar discussions with the cooperating teachers familiarize students with both school-wide and classroom management issues that affect teaching, learning, motivation, and the administration of music programs.

57-356 Elementary Guided Teaching

Fall: 3 units

This is the second level of field experience in the public schools. This course provides for observation and closely supervised teaching experiences with elementary age children in a school setting.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-358 Introduction to Electronic Music

Intermittent: 9 units

This course will allow students to produce original works of electronic music composition in response to strategic listening assignments presented within their historical context. Students will learn critical listening and analytical skills, and be assessed on their electronic music production as well as on their ability to articulate context and structure. This course is for undergraduate music students. Other students may register for it with the permission of the instructor.

57-359 Audiovisual Composition

Intermittent: 9 units

TBA

57-360 Brass Methods

Fall: 3 units

This music education course develops basic brass playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural and amp; visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete and #8212; students should allow enough time in their schedules to complete this requirement.

Course Website: https://cmu.app.box.com/files/1/f/11681158556/1_f_106285571873 (https://cmu.app.box.com/files/1/f/11681158556/1_f_106285571873/)

57-361 Percussion Methods

Fall: 3 units

This class gives the non-percussion major a background in the fundamentals of teaching percussion. The main focus of the course is snare drum. The students spend most of their time learning the basic concepts of beginning snare drum so they will be prepared to teach beginning students of any grade level. Much time is devoted to proper stance, grip, and stroke in order to insure a good foundation for a beginning student. Also covered are the various mallet instruments, timpani, and all small hand percussion. Students will learn about purchasing proper equipment for the various levels of learning in common school programs.

57-362 Woodwind Methods

Spring: 3 units

This music education course develops basic woodwind playing and teaching techniques for beginning and intermediate instrument classes. The course includes training in beginning band program design, aural and amp; visual diagnosis of individual and ensemble playing problems, and methods of accelerating music reading independence in young players. The course requires two off-campus field teaching experiences in local schools. Each field teaching experience will require about 3 hours to complete and #8212; students should allow enough time in their schedules to complete this requirement.

57-363 String Methods

Spring: 3 units

String Methods prepares music educators for work in the public schools. A major portion of class time will be applied to violin and cello techniques. Upon completion of the course, the student will be expected to demonstrate the technical skills of a second year beginning string student. Students will also be introduced to various method books, string supplies, and repairs.

57-364 Conducting Practicum

Fall and Spring: 3 units

This course provides applied conducting experience for the conducting minor.

57-370 Stage Direction

Spring: 3 units

This course provides an internship working with a middle or high school music theater production. Students may participate in coaching, direction, and choreography. In addition, they keep a journal of their experience and submit a final paper describing what they have learned from working with the teachers or professional directors who were responsible for the production. It is suggested that this course be taken during the spring semester when most music theater productions are scheduled.

57-374 Music in the Urban School

Fall and Spring: 9 units

This course will involve workshops with nationally known instructors in eurhythmics, world drumming, contemporary popular music, and classroom management. The course will require attendance at workshops, classroom observations and closely supervised teaching experiences. Schools involved are all inner city schools with a poverty level of 75% or above. This course is offered as the result of a grant received from the Federal Department of Education by the School of Music, the Pittsburgh Public Schools, and the Wilkesburg School District.

57-375 Music in the Elementary School

Fall: 6 units

This course is designed to provide a philosophical background for teaching music in the elementary school and to provide a variety of pedagogical techniques, which are essential when teaching music from Preschool through Grade 6.

Prerequisite: 57-331 Min. grade C

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-376 Music in the Secondary School

Spring: 6 units

This course covers a variety of topics related to the development and the management music programs in secondary schools. Emphasis is placed on the leadership, classroom management, general music and amp; performance course content, and routine administrative planning.

Prerequisite: 57-375 Min. grade C

57-377 Psychology of Music

Intermittent: 9 units

Music cognition is an interdisciplinary approach to understanding the mental processes that support musical behaviors, including perception, comprehension, memory, attention, and performance. Like language, music is a uniquely human capacity that arguably played a central role in the origins of human cognition. This course is survey of current approaches to and theories about the perception and cognition of music. Topics covered include psychoacoustics; the cognitive neuroscience of music; relationships between music and language; the nature of musical knowledge; and debates about aesthetics, evolutionary psychology, and musical universals. At the end of this course a student should be able to identify key theories and hypotheses in music cognition as they relate to memory, emotion, physiology, neurology, acoustics, language, and evolution. They will be able to comparatively evaluate hypotheses and place them in an intellectual context. These objectives will be achieved through critical reading, discussions, and written exercises. There are no prerequisites for this course. It will be helpful for you to know some basic elements of music theory (such as the names for chords, Roman numerals, and so on), but some extra help will be available to cover these topics. Some notational basics will be covered in the first lecture.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-378 Introduction to Music Cognition Research

Intermittent: 9 units

This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as music's adaptive value to the human species, and the determinants of musical taste). Prerequisite: either Harmony I or Intro to Cognitive Psychology. Prerequisites: 57-149 or 57-152

57-381 Collaborative Piano I

Fall and Spring

This class is the first in a series of hands-on courses which allow the student to accumulate experience accompanying in a professional venue. Students will be assigned to a vocal and/or instrumental studio and will have the opportunity to coach repertoire with a professional accompanist. Assignments may include playing for instrumental juries.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-382 Collaborative Piano II

Fall and Spring

Continues 57-381 Accompanying I.
Prerequisite: 57-381

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-383 Collaborative Piano III

Fall and Spring

Continues 57-382 Accompanying II.
Prerequisite: 57-382

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-384 Collaborative Piano IV

Fall and Spring

Continues 57-383 Accompanying III.
Prerequisite: 57-383

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-385 Collaborative Piano V

Fall and Spring

Continues 57-384 Accompanying IV.
Prerequisite: 57-384

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-386 Collaborative Piano VI

Fall and Spring

Continues 57-385 Accompanying V.
Prerequisite: 57-385

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-391 Keyboard Studies (Music Ed)

Fall and Spring: 3 units

This course develops piano skills necessary for work in the elementary and secondary schools. Special emphasis is placed on transposition, score reading, harmonization and sight-reading. This course is required for all music education majors.
Prerequisite: 57-191

57-392 Keyboard Studies (Music Ed)

Fall and Spring: 3 units

Continues 57-391 Keyboard Studies V. This course is required for all music education majors.
Prerequisite: 57-391

57-393 Keyboard Studies Test (Music Ed)

Fall and Spring

This is the keyboard proficiency test which is a requirement for all undergraduate music majors who are music education minors.

57-395 Voice Leadership: Fundamentals, Techniques & Application for the Public Speaker

Intermittent: 3 units

In this course students will learn valuable strategies, techniques and solutions regarding public speaking, the professional voice and interpersonal relationships. Each week will cover a key topic with theory and strategy laid out in lecture form. Students will prepare spoken and written assignments based on the key topics.

57-399 Music-Cinema-Culture

Intermittent: 9 units

The first 100 years of the 20th Century's only original art form, whose advent has brought about tremendous social and cultural changes. Students view selected films, learning first the basics of film theory, cinema's working structures and the function of music. Ultimately, they are able to analyze, in the form of a written essay, the function and value of the music in a particular film and the impact such music has had on society.

57-403 Yoga for Musicians

Fall: 3 units

TBA

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-404 String Quartet: A Social History

Intermittent: 9 units

The string quartet is at once a medium and a genre, even a form which for more than two hundred years has had a special, unparalleled place in Western music. This course examines the development of the string quartet - from its function as an intimate and conversational social setting for amateurs, to its role as a secret repository of composers' most daring thoughts. The string quartet repertoire under discussion spans the first attempts at string quartet writing in the 17th Century, to serialism and microtonal disintegration in the 1960's, to contemporary Pop-Rock fusion experiments. This course also deals with the social and personal histories of four individuals who freed themselves from hegemonic orchestral rules in favor of an instrumental democratic microcosm.

57-405 Concerto: Virtuosity and Contrast

Intermittent: 9 units

The Concerto, one of the most popular forms of music, is also a dramatic form, a drama of contrast between the strength of one body of sound and another (volume), between one type of sound and another (tonal distinction), between the individual and the masses, and finally, between the "Solo" virtuoso and the less gifted "Tutti" players. The goal of this course is to examine the greatest concerti written for all instruments; from Vivaldi's "Concerto for Two Mandolins" to John Adams's "Grand Pianola Music," and much more, while dealing with the social and personal histories of unforgettable virtuosos and the concerti that became their "Battle Horses." The program analyzes great concerti performed by the world's greatest soloists and orchestras.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-408 Form and Analysis

Spring: 6 units

This course provides a working understanding of all styles and genres of Western classical and contemporary repertoire. Students will explore various aspects of the compositional process, from basic organizational structures to the details of individual musical phrases. They will learn to see and to hear the most important compositional features of a piece of music and will develop a deeper understanding of the music they perform, conduct, and compose.

Prerequisites: 57-153 or 57-150

57-409 Puccini's Operas

Intermittent: 9 units

Standing between the 19th and 20th Centuries, Puccini witnessed extraordinary socio-political and cultural shifts sweeping across Europe. His operas reflect such changes through their gradual stylistic adherence to modernity. From theatrical and literary plots to complex relationships with poets, publishers, impresarios, singers, conductors, and political censors, Puccini's operas offer excellent grounds for interdisciplinary dialogue and cultural analysis.

57-411 Musical Theatre on Stage and Screen

Intermittent: 9 units

Defining what musical theater "is" is no easy task. The genre/form/phenomenon as we know it today represents an evolution of embodied practices and interdisciplinary creativity spanning cultures, geographies, traditions, media, and time. Similarly, the history of musical theater, more appropriately, the histories of musical theaters should not be reduced to simple narratives or linear chronologies. Following this idea, this course offers a topical exploration of musicals on stage and screen, focusing on historical developments, production practices, and artistic agency from the mid-nineteenth century to the present. We will not offer a conventional "survey" of musicals starting from an arbitrary point "way back when" and ending with the state of things in 2022. Like the "concept musicals" of the mid-twentieth century, a non-linear structure allows us to consider broader connections across our subject(s). In addition to repertoire case studies, we will explore the historiography of musical theater; the process of developing musicals from page to stage; the function and labor of performers, administrators, stage directors, stage designers, and technical personnel in making musicals happen; musicals in various media; musicals in the time of the coronavirus pandemic; and concerns of social justice in reviving established works and producing new works. Assignments will include short analysis presentations and written responses. There is no performance component with this course.

57-412 Opera Since Wagner

Intermittent: 9 units

In the 400-year arc of opera history, the last 125 years have seen the genre's apogee, perigee, and current renaissance. Between the Wagnermania of the late nineteenth century and today's vogue for both opera and "popera," new opera production slowed greatly in the third quarter of the last century as composers rejected its traditions and audiences turned increasingly to rock and pop. In this course, we will survey this trajectory by viewing and analyzing eight repertoire staples: Wagner Parsifal Debussy Pell and #233;as et M and #233;isande Puccini Turandot Berg Wozzeck Gershwin Porgy and Bess Britten Peter Grimes Messiaen Saint Fran and #231;ois d'Assise Reich Three Tales We will also become acquainted with other works related to these staples, from Strauss to Saariaho and Tan Dun, and ask numerous questions. What can these operas' characters and techniques tell us about late modern subjectivity? What happened to the great national traditions? In what musical styles has opera flourished and languished? How have audiences changed? How has the notion of opera itself changed, from the nature of its heroes and heroines to its performance forces and media? The goals of this course are to 1) promote intimate knowledge of the eight core operas; 2) encourage familiarity with numerous related opera plots, opera composers, and twentieth- and twenty-first-century musical styles; 3) broaden literary and musical analytical tools to include historical, aesthetic, and (multi)cultural perspectives on opera; and 4) improve oral and written communication skills about opera. Requirements: Attendance at opera screenings, readings, quizzes, small written assignments, and a 17 to 20-page research paper on an opera of your choice written since 1850. Required text: Mervyn Cook, ed. The Cambridge Companion to Twentieth-century Opera (2005).

Prerequisite: 57-284

57-413 The Interpretation of Music

Intermittent: 6 units

What does it mean to "interpret" music? How does performance differ from interpretation? How do we distinguish a good interpretation from a bad one? To answer these questions, this course examines Metaphor, History, Influence, Meaning, Analysis, Performance, Musicology, and other concepts, applying them to works like the Mendelssohn Violin Concerto, Chopin's Fantasie Impromptu, Beethoven's "Ghost" Trio, and Debussy's "Voiles." Our readings draw mainly from Lawrence Kramer's *Interpreting Music* (2011). Our goal is to appreciate the complexity and nuance inherent in the process of music making and to formulate our individual values in the interpretation of music.

57-414 Music and Nature

Intermittent: 9 units

Musicians and philosophers have long explored the rapport between music and nature, tracing music's origins alternatively to nature and human culture and defining nature differently according to their time and place. This course will examine the opposition between nature and culture through both musical compositions and philosophical writings. We will study theories of the origin of music (from Lucretius to biomusicology), theories of music that seek justification by appealing to nature (from Boethius to Grisey), and theories that question whether natural sounds can be music. We will also examine musical representations of place, weather, and animals through the perspectives of ecocriticism and notions of the pastoral. Repertory will include Vivaldi's "Spring" Concerto, Beethoven's "Pastoral" Symphony, Wagner's Ring of the Nibelung, Mahler's Symphony No. 3, and Debussy's La Mer. We will compare landscapes by Sibelius and Copland, birds by Dvorak, Bart and #243;k, Ravel, Stravinsky, and Messiaen, and whales by Crum and Hovhanness. We will also treat statements on the environmental crisis by composers Harrison Birtwistle, Philip Glass, Peter Sculthorpe, and John Luther Adams. Reading, listening, discussion, 2 short papers, 1 long paper, oral presentation.

Prerequisite: 57-285

57-415 Mozart Operas

Fall: 6 units

In the genre with the highest stakes and the highest failure rate, Mozart composed the earliest operas to have staked a permanent place at the center of the repertory. This course seeks to account for his success, to explain why he succeeded where others failed and what has made his operas beloved for over 225 years. We begin with a brief overview of all of Mozart's operas and discuss the types of opera in circulation in late 18th century Austro-Hungary, especially opera seria, opera buffa, and Singspiel, and the pressures that shaped the music and libretto of each production, from the type of patronage to the style of recitative. Then we examine *The Marriage of Figaro*, *Don Giovanni*, and *The Magic Flute* at a pace of about one act per class session, looking at poetry, dramaturgy, stagecraft, acting, performance practice, character development, theme, and politics, always through the filter of Mozart's music, especially its melody, reform elements, blurring of genre and affect, vocal counterpoint, use of topics, and musical symbolism.

Prerequisite: 57-285

57-416 Globalization of Classical Music: USA, Turkey, Japan

Intermittent: 6 units

What sounds are made when cultures clash? What issues are at stake when composers and performers approach music with strong ties to music of other cultures, such as Debussy's Iberia and Copland's El Salon Mexico, or when, like Bartok, they introduce elements of a stylized folk music into the concert hall? How did the Western classical tradition come to be mastered in countries worldwide? Where is it resisted and why? When composers from non-Western traditions engage with classical traditions, what do they give up and what do they gain? In what ways do they seek to retain style traits or instruments from their home country? and why? Do countries all adopt this tradition in the same way and for the same reasons? How do such varied negotiations of cultures define national identities? This course addresses such questions by focusing on the role of Western classical music in the history of the United States, Turkey, and Japan - countries with very different histories of engaging with European culture, yet sharing a decisive adoption of European-based modernity in the twentieth century.

Prerequisite: 57-285

57-417 Major Vocal Performance Ensemble

Fall and Spring: 6 units

There are two choral ensembles. Concert Choir is a select ensemble of approximately 40 voices of superior vocal/musical talent and experience in the choral idiom. Performance requirements are more stringent than those of the Repertory Chorus. Repertory Chorus is an ensemble of undetermined size. Emphasis is placed on vocal technique and development, musical skills in the rehearsal with minimum performance requirements. Audition required.

57-418 Major Instrumental Ensemble

Fall and Spring: 6 units

There are two instrumental ensembles: Orchestra and Wind Ensemble. Rotating seating plans, within and between ensembles, will prevail at the discretion of the Director of Orchestral Studies and the Director of the Wind Ensemble. The instrumental faculty will be consulted. All music majors who are required to enroll in an instrumental ensemble must audition for placement and enroll in Major Instrumental Ensemble. Audition required.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

57-420 JIVE - CMU Jazz Choir

Fall and Spring: 3 units

A highly selective group of mixed voices who perform contemporary jazz and pop vocal arrangements. Open to all CMU students. Previous registration or a successful audition for Jazz Vocal Ensemble will meet the prerequisite requirement. Contact the director, Betsy Lawrence and [lt;blawrenc@andrew.cmu.edu](mailto:blawrenc@andrew.cmu.edu) and gt;, to schedule an audition. Prerequisite: 57-420

57-421 Exploded Ensemble

Fall: 6 units

Exploded Ensemble is a group dedicated to the performance of music that pushes the boundaries of traditional performance and composition. The ensemble has a strong emphasis on electro-acoustic performance technique, experimental approaches to staging and amplification, and visuals (live video, computer controlled lighting, wearable technology, etc.). The group will perform works by new/experimental/electro-acoustic composers and will create new arrangements of works for which scores may not currently exist - for example, music by rock bands, electronic musicians, and sound artists. The overall goal of the ensemble is to explode the idea of traditional concert music performance. In so doing we shall advance student skills in music performance, music appreciation, and to advance the very important conversation on the future of concert music. Students interested in this course who have not had the prerequisite should contact the instructors.

Course Website: <https://courses.ideate.cmu.edu/57-421> (<https://courses.ideate.cmu.edu/57-421/>)

57-423 Repertoire Orchestra

Fall and Spring: 3 units

This course thoroughly acquaints participants with the standard works one would expect to encounter as part of a career as an orchestral player. Assigned repertoire will be read each class session. All students are eligible to register for this course by special permission. Students who are not placed in the Carnegie Mellon Philharmonic are given priority for registration.

57-424 Percussion Ensemble

Fall and Spring: 3 units

This ensemble is open to all percussion majors.

57-425 Expanded Music Performance

Intermittent: 9 units

In his 1970 manifesto Expanded Cinema, Gene Youngblood presented the idea that emerging video technology would lead to a new form of cinematic expression in which art and life are united. In this course we will explore this idea in the realm of music through the creation of new technologies that will expand the possibilities of live performance. The technologies we develop will be used in a series of public concerts by CMU's Exploded Ensemble, a group of high-caliber musicians dedicated to electro-acoustic performance of avant-garde concert music. The course will work closely with the Exploded Ensemble to develop expansive technologies that will transform the music the group performs. These transformations may take place in many different modalities. In the realm of sound we will investigate several areas: the development of new software for sound processing and synthesis, the creation of new instruments, and experimental methods of sound amplification and distribution. In the visual realm, we will develop software for live video performance, will investigate experimental techniques for video projection including mapping and the use of depth cameras, and will develop tools for computer controlled lighting systems. In the physical realm we will develop wearable technologies for performers, sensor-based responsive systems, and will explore experimental approaches to costume and decor.

57-427 Advanced Seminar in Film Musicology

Intermittent: 9 units

This course has been designed primarily for advanced students wishing to apply to film scores analytical methodologies pertaining to historical musicology, cultural studies, and genetic criticism. The films screened and the music analyzed in this course follow at first the historical development of cinema. Then, the syllabus focuses on the film music of Ennio Morricone in honor of his 90th birthday and on final presentations of film soundtracks selected by the students. Prerequisites include some knowledge of music history, theory, practice, or the instructor's permission.

57-428 Theatre Orchestra

Intermittent

Instrumental ensemble which accompanies a production in the School of Drama.

57-429 Beginning Piano for Children I

Fall and Spring: 6 units

This course is the first of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.

Prerequisite: 57-273

57-430 Music of Iran

Intermittent: 9 units

The Iranian civilization is one of the oldest continuing civilizations in the world. Music has played an important role in the continuation and preservation of this ancient culture. In this course, the traditional, folk, and contemporary music of Iran will be studied and discussed. The focal point of the course will be the Persian modal system, the D and #225;stg and #226;h. Starting with a historical survey of the ancient and medieval Persian music, different aspects of the D and #225;stg and #226;h system will be demonstrated and discussed. In addition, religious music and folk music of Iran as well as Iranian contemporary music will be discussed during the course.

57-431 Italian Literature and Repertoire

Spring: 3 units

The course provides a bibliography of repertoire in the Italian language. Material will include art songs and cantatas and will be presented via individual student performances in class, listening to recordings and group survey of repertoire. Reading and writing assignments will serve to establish historical perspective as well as programming considerations.

57-432 French Literature and Repertoire

Spring: 3 units

This course examines French songs for solo voice. Representative works from 18th through 20th centuries will be studied in the context of music history, style and programmatic considerations. Classes consist of individual performance, listening to recordings, and group survey of repertoire. Reading and written assignments establish historical perspective as well as programming considerations.

57-433 Musical Theatre Literature and Repertoire

Fall: 3 units

This class covers music theatre repertoire for two semesters, beginning chronologically with the operetta and concluding with current theatre composers. Each student will be assigned songs to prepare from these musicals. These songs can also be used for music theatre auditions. Students are expected to research all assigned songs and perform them in the proper style. Notebooks must be kept which include all lecture notes, class song assignments and music for songs performed individually.

57-434 Musical Theatre Literature and Repertoire

Spring: 3 units

Continues 57-433 Musical Theatre Literature and Repertoire.

Prerequisite: 57-433

57-435 German Literature and Repertoire

Spring: 3 units

The course examines German repertoire composed for solo voice. Representative works from the Baroque period through the 20th Century are studied in the context of musical style, vocal demands and programmatic considerations. Repertoire focuses on art songs and cantatas, but also includes certain oratorio excerpts, which are included frequently in recital programs. A bibliography of German repertoire is compiled through individual or group performance of songs, listening to recordings and through research assignments, the latter of which focuses upon the works of specific composers. Reading assignments are included to establish an historical perspective.

57-436 English/Contemporary Literature and Repertoire

Spring: 3 units

The course provides a bibliography of repertoire in the English language. Material will be limited to art songs and will be presented via individual student or group performances in class, and recorded performances. Research assignments will be required for selected anthologies or for works by specific composers. Repertoire will be examined according to vocal requirements, musical style, and programmatic function. The repertoire will consist primarily of works by British and American composers, but works by Russian and Spanish composers will also be included.

57-437 Literature and Repertoire

Fall and Spring: 3 units

This course deals with literature and repertoire for orchestral instruments. There are multiple sections organized by instrument categories or specific instruments.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49t02lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49t02lilzk2/>)

57-438 Multitrack Recording

Fall and Spring: 9 units

This course builds upon the ideas learned in Sound Recording (57-337), but with an emphasis on close microphone techniques and popular music styles. Students will work in small groups and complete at least two recording projects. \$10.00 materials fee.

Prerequisites: 57-651 or 57-341 or 57-342 or 57-337

57-441 Analysis of 19th Century Music

Intermittent: 9 units

This course will provide students with a variety of tools for the analysis of music from Schubert to Mahler and early Schoenberg. The primary emphases will be on small-scale (chord-to-chord) harmonic organization, on the larger-scale organization of tonal centers, and on form, but other issues will also be explored (e.g. rhythm and meter, text/music relations). The course will sample a wide range of repertoires, including solo piano music, orchestral music, and opera, and it will have a special emphasis on chamber music including the German Lied.

57-442 Analytical Techniques

Fall: 9 units

What is music analysis and why is it important? How do we talk about our experiences with music? If I can analyze music, will it help get a job? An analytical technique is a way to perceive or embody music with someone else: to find resonance or even difference without presenting one's perception as objective and universal. We use analytical techniques all the time in explicit ways and implicit ways when we make and listen to music. In this course, we will study western analytical techniques in their application to western classical, jazz, popular, and non-western musics. When appropriate, we will discuss non-western techniques, but they will not be a focus. We will learn traditional analytic methodologies and explore philosophical and cultural relationships between value, culture, identity, and analysis. There will be weekly readings, listening, and analysis assignments. In the first seven weeks we will focus on the analysis of western classical tonal music. In the second half of the semester we will focus on transcription and improvisation in diverse musical contexts. Students will complete a project in each of these three areas. This course utilizes in-class discussion and performance by all participants. The goal of this course is to improve your ability to conceptualize and perform new music and to enhance your engagement with your current repertoire.

Prerequisite: 57-408

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285568801
(https://cmu.app.box.com/files/0/f/11681158556/1/f_106285568801/)

57-444 Principles of Counterpoint

Intermittent: 9 units

This course explores the development of Western music composed with multiple independent parts. The first half of the course traces the history of part-writing from medieval organum to the twenty-first century. Emphasis is given to study of pre-Baroque and twentieth-century music, and to the conceptual shifts that occurred moving in and out of the common-practice period. The second half of the course examines, across multiple musical styles, specific contrapuntal techniques such as imitation and ground bass forms. Assignments include both writing exercises and analysis, culminating in a term project on a topic selected by the student.

Prerequisites: 57-152 or 57-149

57-445 Counterpoint in 18th Century Composition

Intermittent: 6 units

In this course the student will study how to write two-part counterpoint within the harmonic framework of 18th-century instrumental music. The focus of study will be J.S. Bach's inventions, and writing will be directed towards composing several complete inventions in that style. Prerequisites: Harmony I and Harmony II or permission of the instructor. This course is designed for composers, theory minors, Bach lovers, keyboard majors, and anyone who wants to seriously sharpen their tonal writing skills.

Prerequisite: 57-408

57-446 Renaissance Counterpoint

Intermittent: 6 units

In this course the student will study how to write vocal counterpoint using the classic "species" approach, based on the style of Renaissance masters Palestrina, Lassus, and Victoria. The latter part of the course will extend the study to instrumental music of the 16th century, and explore the development of chromaticism in avant-garde composers of the time. Reading about and listening to Renaissance music and composers will be included as background context for the theory work. Daily writing exercises in the first part of the course will lead to a term project producing a performable piece of music by the end of the semester. This course is designed for composers (both for writing technique and college teaching preparation), theory minors, early music lovers, choral singers and conductors, church musicians, and anyone who wants to sharpen their writing skills. Prerequisite: Harmony I or permission of the instructor (demonstrated competence in reading treble and bass clef, and intervals).

Prerequisite: 57-408

57-447 Harp Pedagogy

Fall and Spring: 3 units

TBA

57-448 Brass Pedagogy

Fall: 3 units

In this course we introduce the "Art of Teaching". In this case, to teach, develop and encourage young brass players just starting an instrument or who are in their early stages of development. Concepts of basic brass pedagogy will involve the following topics: Music as Metaphor; Teaching young students; Listening; Developing a Concept of Sound; Posture; Breathing; Embouchure; Articulation: Single Tonguing, Multiple Tonguing; Mouthpiece playing; The Warm-up; Slurring; Intonation; The Upper Register; Endurance; Vibrato; Dental Braces; Orchestral Playing; Performance Preparation; Taking Auditions Brass students will leave CMU with a basic understanding of the pedagogical needs and requirements of beginning and inexperienced students, so that they may begin private teaching studio upon graduation.

57-449 Beginning Piano for Children II

Fall and Spring: 6 units

This course is the second of two courses in a year-long internship in the piano teaching of young children, combining class and private instruction: a study of the basic teaching/learning process as applied to piano teaching, covering comprehensive step-by-step presentation in reading, rhythm, ear training, sight reading, technique, and musicianship. Under supervision, students will teach the weekly group class and private lessons. Weekly conferences will be held for learning the presentation of materials for class teaching, analyzing pedagogical problems, and developing communication skills with both young pupils and their parents.

Prerequisite: 57-429

57-450 Audience Development

Intermittent: 6 units

TBA

57-451 Teaching Artists in the Community

Intermittent: 6 units

This course puts you in a working relationship with experts who serve as teaching artists to inspire people of all ages to engage with music in meaningful ways. You will also learn how to build a successful private studio.

57-452 Collaborative Project in Music Entrepreneurship

Intermittent: 6 units

The project for Fall 2023 is to develop and pilot a program that uses sound and music to reduce anxiety and improve mental health on campus. Outcomes will be measured and documented for evaluation by CMU wellness staff with a possibility for long-term implementation. Any CMU student interested in sound healing and mindful music-making is welcome to join this class. This is an advanced entrepreneurship course and requires a solid foundation of project management and interpersonal skills. Class size is limited to a team of six self-driven students with a project that has business potential or solves a problem. Students work as a team, usually in collaboration with a community partner. A high level of personal initiative and professionalism is required.

57-454 The Freelance Musician

Intermittent: 6 units

This course will put you in touch with innovative artists, managers, web designers, career consultants, and other professionals who want to help you succeed. There is nothing theoretical about this course: you'll perform "real gigs for real clients" who will offer feedback on your professionalism. You'll build a website with expert support and gain clarity on how music fits into your higher purpose. The objective of this course is to make you "roadworthy" as a professional musician, equipping you with the tools, skills, and mindset that would make people want to work with you again and again. You can think of it in three stages: "building the car" (professional portfolio), "tuning the engine" (communication); and "mapping the route" (strategy) to put you on the road to success. No prior knowledge or experience is required to take this course. You have already spent thousands of hours practicing to become a fine musician. Turning your artistry into a livelihood requires an entirely different skillset, which can be jumpstarted (in only about 50 hours) so let's get going!

57-455 Shaping Time in Performance

Intermittent: 9 units

This course will look at basic questions that performers face: Which level of pulse do I want to feel as the main one? How can I shape a pulse expressively? Which measure in a phrase is felt as a main goal, especially when the phrase contains an unusual number of measures? How can multiple tempi be meaningfully related? Among many important formal arrival points, which are the most important? In addition to these questions, we will also look at recent work on ways in which 18th-century musicians may have understood meter very differently from most musicians today. These alternate perspectives open new possibilities for hearing and shaping the flow of musical time in baroque and classical music. These issues will be pursued from two directions. We will develop simple theoretical tools that can make score analysis a helpful input to the decisions that performers make about such questions. We will also examine audio and video recordings by famous artists to see both how they dealt with these issues and what new questions are raised. Week-to-week work will include reading, listening, and score analysis. Students will write term papers that either use one of the main perspectives developed in class (starting from scores or starting from recordings) or else combine the two. They will also give presentations about their projects to the class.

57-456 Marketing for Musicians

Intermittent: 6 units

What is your message? Who is your audience? How do you reach them? These are among the topics we'll explore in this course. Group projects and case studies help us identify the key aspects of one of the most important aspects of any music career. Being a great musician won't do you any good if no one knows you exist! By the end of the semester, students should be able to understand such concepts as branding, marketing, reach and advertising; identify audience segments and target messages to those segments; create compelling marketing materials, including bios, group and program descriptions, websites and flyers; work with teams to try out a variety of marketing strategies in real-world circumstances; learn to capitalize on social media and use it to effectively build and communicate to an audience; learn to write effective and powerful marketing copy (bios, sales pieces, etc.); examine competitors and market leaders to look for opportunities and best practices.

57-457 Mental training for peak performance

Intermittent: 6 units

Perform in Kresge Theatre regularly and gain tools for overcoming performance anxiety to own the stage and play your best. Everyone gets nervous, but it doesn't need to be debilitating. Learn how to calm your mind and turn nervous energy into mental focus. Guest faculty, PSO musicians, and visiting artists share their challenges and offer strategies for audition preparation, effective practicing, self-care, conflict resolution, and other mind-body topics.

57-458 Business of Music

Intermittent: 6 units

This class will teach you the fundamentals of how to survive in the music industry. A diverse set of speakers, hands-on projects tailored to your interests and needs and group activities will introduce you to the challenges you'll face during your career. How to manage your money, what you need to know about copyright, whom do you need on your side? We'll cover all of these and more!

Course Website: https://cmu.app.box.com/files/1/f/11681158556/1/f_106285572641 (https://cmu.app.box.com/files/1/f/11681158556/1/f_106285572641/)

57-459 Score Reading for Composition Majors and Conducting Minors

Spring: 6 units

This course is a practical, hands-on learning experience. Students learn by doing and observing other students. All work is done at the keyboard. It is for graduate collaborative piano majors, junior and senior composition majors, and junior and senior conducting minors with good keyboard skills who have completed Keyboard Studies or have otherwise satisfied the requirement. Other music majors with good keyboard skills who have completed Keyboard Studies or have otherwise satisfied the requirement can take this course with instructor permission.

Prerequisites: 57-408 or 57-191

57-460 Collaborative Project in Music Entrepreneurship

Intermittent: 6 units

This is an advanced entrepreneurship course, designed to simulate the atmosphere of "real world" project collaborations. You will develop leadership as you work on real projects that make a positive impact in the community. Monique Mead serves as your primary consultant, helping you keep the project on track and connecting you with others who can support your cause. Outside of class time, you will hold planning sessions with team members, perform interviews, and meet with outside collaborators. Project for Fall 2017 is a continuation of Spring 2017: Create a greater sense of community at the School of Music.

57-461 Aural Analysis and Basic Improvisation

Intermittent: 9 units

Where are we now? Musicians often face analytical questions in performing situations. What scale degree is the trumpet playing? What chord are we playing now? What countermelody are the altos singing? What is the form, and where are we in it? The purpose of this course is to enhance students' abilities to answer these kinds of questions in real-time, real-world performance situations, apart from the score. The primary skills developed in the course will be hearing melodic scale degrees, hearing harmonies, memorizing short melodic fragments, identifying short harmonic idioms by ear, hearing two-voice contrapuntal music, and improvising over repeated chord progressions. A variety of conventional and unconventional games and exercises will be employed, involving notating, singing, and using the students' main instruments. We will also put these skills to use in doing larger-scale analysis by ear of longer passages, focusing especially on form, including entire movements. Improvisation comes into the course because perception and production are deeply intertwined; fun improvisation exercises, mostly using the idioms of popular music, will strengthen aural abilities much more than passive identification and dictation exercises could alone.

Prerequisite: 57-408

57-463 Consumer Driven Composition for Contemporary Media

Intermittent: 3 units

This course aims to augment each student's compositional skill set with technological skills and industry-specific knowledge that will provide them the flexibility and confidence to interface with consumers and more readily monetize their music. This course is intended to be part lecture to allow for quick and concise transfer of information, and part seminar to allow all class participants the ability to learn from each other as they pitch ideas, receive feedback, and evaluate the success of their peers' work. The course is for Sophomore, Junior, Senior, and Graduate Composition Majors. The only required prerequisite is 57-101 Introduction to Music Technology. 57-347 Electronic and Computer Music is encouraged, but not required.

57-464 Music & Money

Intermittent: 6 units

This course is intended to develop in the student a broad knowledge of the music business, an entrepreneurial mindset applicable to it, and to encourage curiosity about future possibilities in the field. Students will examine the musical groups, ensembles, and institutions from the standpoint of economic, business and marketplace realities. Musical entities will be considered and studied not for their inherent artistic merit but as commodities affected by the same forces as any other consumable. Students will acquire a basic understanding of the forces - economic, financial, psychological, societal - that affect entities in the music field. They will also be called upon to think creatively and entrepreneurially about possible directions for existing musical entities. Students will become familiar with current methods of musical content creation, delivery platforms, advertising and marketing avenues, and revenue streams. Students will consider the history, economic structure, opportunities, and the challenges faced by each. Students will encounter and react to case studies taken from the music field about individuals and groups and the decision-making mechanisms at work in each, and the outcomes of the decisions taken by these individuals and groups.

57-465 Eurhythmics Applications for Performing and Teaching

Fall: 6 units

Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. For musicians, meaningful rhythmic movement reinforces understanding of music concepts while focusing awareness on the physical demands of artistic performance. This approach to musical problem solving is applicable also to studio and classroom teaching.

Prerequisite: 57-164

57-466 Eurhythmics Applications for Performing and Teaching

Fall: 6 units

Rhythm is about time and timing. Dalcroze Eurhythmics is an exploration of the rhythm inside us. Experiencing rhythm through music and movement brings awareness and understanding of our own inner rhythm as well as rhythm in all the arts and beyond. For musicians, meaningful rhythmic movement reinforces understanding of music concepts while focusing awareness on the physical demands of artistic performance. This approach to musical problem solving is applicable also to studio and classroom teaching.

Prerequisite: 57-164

57-467 Production: Crew

Intermittent: 3 units

Technical crew for the fully staged production presented by the 57-471 Production: Performance class. Class participants serve as build and run crew for the production.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49t2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49t2lilzk2/>)

57-468 Production: Crew

Spring: 3 units

Technical crew for the fully staged production presented by the 57-472 Production: Performance class. Class participants serve as build and run crew for the production.

57-469 Production: Scenes

Fall: 6 units

Preparation of operatic and musical theatre scenes with a public performance of the scenes at the end of the semester. Specific repertoire based upon the proficiency of the individual student.

Prerequisites: 57-212 and 57-340

57-470 Production: Scenes

Spring: 6 units

Preparation of operatic and musical theatre scenes with a public performance of the scenes at the end of the semester. Specific repertoire based upon the proficiency of the individual student.

Prerequisites: 57-212 and 57-340

57-471 Production: Performance

Fall: 6 units

Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.

Prerequisites: 57-212 and 57-340

57-472 Production: Performance

Spring: 6 units

Preparation of an operatic or musical theatre production with a fully staged public performance of the production at the end of the class.

Prerequisites: 57-340 and 57-212

57-473 Production: Performance

Fall and Spring: 3 units

TBA

57-476 How Music Works: An Affective History

Intermittent: 6 units

This is an historical survey of (a) aesthetic theories about music and human agency and music's affects and effects, thus its significance and even its very existence and of (b) actual utilizations of music. Theories range from Aristotle's catharsis to trauma theory and neuromusicology in our time. The applications range from the biblical David's therapeutic harp playing in the court of King Saul (11th C. BCE) to U.S. interrogations in Iraq (21st C. CE); from Vodun and exorcisms in other cultures to MUZAK in our own. In short, it's a chronological survey of what peoples have believed about music's powers and, consequently, how music has been used and abused. The dialectic between theory and applications is reflected in the assignments. This seminar is heavily focused on reading, as well as written and verbal discussion. There is also a long-term field project.

57-477 Music of the Spirit

Intermittent: 6 units

This guided listening course is a musical exploration of spirituality, a sociological and ethnomusicological survey organized around comparative religions. While the majority of repertoire will be from the Western Classical tradition, musics of a variety of cultures will be included. The music will be organized by particular religious traditions and by universal themes, such as community, death/afterlife, birth/new birth, martyrs/heroes, transcendence / immanence, meditation/contemplation/trance, etc. Most course materials, including streaming audio, are online, with one meeting per week in the classroom. Will include participatory introductions to numerous forms of chant. Requires oral and written reports.

57-478 Survey of Historical Recording

Intermittent: 6 units

The histories of music and technology have long been intertwined. Their symbiosis intensified with the harnessing of electricity in the third wave of the Industrial Revolution. This course will expose you to many of the best practitioners of music. But it will do so with an eye and an ear and towards the media by which we have known them. In short ... The music. The personalities. The media. This seminar is heavy on listening (guided playlists online via Canvas). Writing includes reviews and a researched feature article.

57-480 History of Black American Music

Fall: 6 units

Come and explore the rich musical heritage of Black America. This course will survey the music of Black America beginning with the African legacy and continuing through the music of the Twentieth Century. Class sessions will involve discussions, listening, viewing of films, and reports by students on topics of individual interest. Discussions will involve, historical, cultural and political perspective, as well as the music and composers themselves. Lecturing will be at a minimum. Innovative testing in quiz show format will be used. No prerequisites required. Open to all upper level undergraduate students.

57-485 History of the Symphony

Intermittent: 9 units

This course is a study of major symphonic works from 1750 to the modern period. For reasons we will examine, symphonic literature, and the symphony in particular, has long been considered Western art music's greatest monument to its history. Composers have agonized over its composition, conductors have devoted careers to it, and audiences have deeply and zealously expressed their admiration for it. We want to understand why this music is so revered and long-lasting. And we want to understand how the aesthetics of these works have been shaped by their historical, socio-cultural contexts, and how their meaning and value continue to change. Over the course of the term, we will analyze some of the great examples of this genre. We will place them in their historical, socio-cultural contexts with primary sources and insightful academic scholarship. Your critical listening, reading, and thinking skills will be expanded as we delve into almost three centuries of music and writings.

57-487 Advanced Solfege III

Fall: 3 units

Covers the same concepts as Solfege IV in more challenging material, from Bach chorales in open score to excerpts by Bartok, Honegger, Stockhausen, or Boulez. Dictations are three-part contrapuntal and difficult harmonic three and four parts.

Prerequisite: 57-186

Course Website: https://cmu.app.box.com/files/0/f/11681158556/1/f_106285567265 (https://cmu.app.box.com/files/0/f/11681158556/1/f_106285567265/)

57-488 Advanced Solfege IV

Spring: 3 units

Continues 57-487 Advanced Solfege III.

Prerequisite: 57-487

57-489 Practice Teaching (Elementary)

Fall and Spring

Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-490 Practice Teaching (Secondary)

Fall and Spring

Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-491 Solfege for Conductors I

Intermittent: 3 units

TBA

Prerequisites: 57-488 or 57-184

57-496 BXA Studio (1st semester)

Fall and Spring: 9 units

TBA

57-497 BXA Studio (2nd semester)

Fall and Spring: 9 units

TBA

Prerequisite: 57-496

57-498 BXA Studio (3rd semester)

Fall and Spring: 9 units

TBA

Prerequisite: 57-497

57-499 BXA Studio (4th semester)

Fall and Spring: 9 units

TBA

Prerequisite: 57-498

57-500 Major Studio (Voice)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-501 Major Studio (Piano)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-502 Major Studio (Organ)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-503 Major Studio (Harp)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-505 Major Studio (Violin)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-506 Major Studio (Viola)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-507 Major Studio (Cello)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-508 Major Studio (Double Bass)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-509 Major Studio (Guitar)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <http://www.music.cmu.edu/pages/insidemusic-coursesyllabi> (<http://www.music.cmu.edu/pages/insidemusic-coursesyllabi/>)

57-510 Major Studio (Flute)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-511 Major Studio (Oboe)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-512 Major Studio (Clarinet)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-513 Major Studio (Bassoon)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-514 Major Studio (Saxophone)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-515 Major Studio (Horn)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-516 Major Studio (Trumpet)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-517 Major Studio (Trombone)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-518 Major Studio (Euphonium/Baritone)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-519 Major Studio (Tuba)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2> (<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-520 Major Studio (Percussion)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-521 Major Studio (Composition)

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)**57-522 Major Studio (Bagpipe)**

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)**57-523 Major Studio (Electronic Music)**

Fall and Spring: 9 units

A one hour private lesson per week for all music majors.

57-557 Vocal Methods

Spring: 3 units

This course enables each student to develop a pleasant, healthy, and musically expressive voice and effective vocal pedagogy.

57-558 Observation

Fall and Spring: 3 units

This music education offering is an independent study course designed to introduce students to a range of K-12 instructional practices through observation of elementary and secondary school teachers. Students will identify strategies that impact learning in the areas of pedagogy, student motivation, classroom management, and accommodations for special learners. Students complete this course by arranging 20 prescribed classroom observations in local schools - multiple observations may be completed at each school visit. In order to complete the observations in one semester, students should schedule an open 3-hour time block one day per week between 8 am and 3 pm.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)**57-559 Music and Triads: Before/Beyond Roman Numerals in Western Music**

Intermittent: 9 units

In many western traditions, the triad is a foundational element for musical construction. Though the ingredient is consistent across many styles, how it is used changes according to time, place, and even for the individual piece. This course is a deep dive into the ways in which triads are used in a variety of western traditions. We will track common practices and notable manipulations across diatonic music, modal, non- and poly- and pan-tonal repertoires, and use different methods of notation, annotation, and engagement to better understand how the triad is used in music. Through listening, annotation, performance, and discussion, students will develop methods to identify triad and triad-expanding material, and to build usable analytical practices that are sensitive to the unique sonic footprints of specific musical styles. They will hone skills to communicate their findings, and transfer their interpretation into performance and creative practice. Students will be assessed through regular listening, analytical, and creative assignments, as well as in-class discussion and a final project or paper.

57-560 Electronic Music Seminar

Fall and Spring: 3 units

tba

57-570 Music and Technology Seminar

Fall and Spring: 1 unit

The Music and Technology Seminar is a weekly meeting to discuss topics in the areas of computer music, electronic music, musical acoustics, music perception, music technology, music information retrieval, music interfaces, music systems and software, and music theory. Presentations on these various topics are made by graduate students and faculty. The seminar is open to the University and broader community, but students should only enroll if the seminar is part of their degree requirements.

57-571 Music and Technology Project

Fall and Spring: 12 units

TBA

57-572 Music and Technology Project

Fall and Spring: 12 units

TBA

57-588 Junior Recital Voice

Fall: 1 unit

tba

57-589 Senior Recital Voice

Fall: 1 unit

tba

57-590 Internship

All Semesters

TBA

57-591 Dalcroze Pedagogy/Practice Teaching

Fall: 3 units

This course gives hands-on experience in applying Dalcroze principles in teaching situations. It is designed for students interested in learning about the teaching of Eurhythmics, general Music Education, and for those considering the Dalcroze Certificate. The class will meet in a three week rotation of two Thursday evenings followed by a Saturday morning with the Preparatory School children's classes.

57-593 Vocal Coaching

Fall and Spring: 1 unit

TBA

57-597 Senior Project

Fall and Spring: 1 unit

A composition for orchestra required of all senior composition majors.

57-598 Junior Recital

Fall and Spring: 1 unit

A half recital required of all junior performance majors.

57-599 Senior Recital

Fall and Spring: 1 unit

A full recital required of all senior performance majors.

57-603 Practice Teaching (Elementary)

Fall and Spring

Experience in working with elementary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty.

Prerequisites: 57-355 and 57-393

57-604 Practice Teaching (Secondary)

Fall and Spring

Experience in working with secondary students in a public school setting. The teaching is supervised by an experienced public school teacher and members of the CMU music education faculty. Students may choose a vocal or instrumental emphasis in the secondary placement.

Prerequisites: 57-355 and 57-393

57-607 Vocal Methods

Spring: 3 units

This course enables each student to develop a pleasant, healthy, and musically expressive voice and effective vocal pedagogy.

57-608 Observation

Fall: 3 units

This music education offering is an independent study course designed to introduce students to a range of K-12 instructional practices through observation of elementary and secondary school teachers. Students will identify strategies that impact learning in the areas of pedagogy, student motivation, classroom management, and accommodations for special learners. Students complete this course by arranging 20 prescribed classroom observations in local schools - multiple observations may be completed at each school visit. In order to complete the observations in one semester, students should schedule an open 3-hour time block one day per week between 8 am and 3 pm.

57-610 Internship

Fall and Spring

A student can receive credit for an unpaid internship in a music related field. The amount of credit is determined by the number of internship hours.

57-611 Independent Study in History

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-612 Independent Study in Theory

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-613 Independent Study in Research

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-614 Independent Study in Performance

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-615 Independent Study in Literature and Repertoire

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-616 Independent Study in Sound Studies

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-617 Independent Study in Electronic and Experimental Music

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-618 Independent Study in Conducting

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-619 Independent Study in Opera

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-620 Independent Study in Solfege

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-621 Independent Study in Eurhythmics

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-622 Independent Study in Sound Recording Production

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-623 Independent Study in Studio Recording Project

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-624 Independent Study in Special Music Project

Fall and Spring

Students undertake a critical examination of some aspects of music on an independent basis under the supervision of a full-time faculty member. They choose their topic and contract with the Project Director (faculty sponsor) as to when and how the project will be completed. Open to upperclassmen.

57-627 Independent Study in Supervised Teaching

Fall and Spring

TBA

57-641 Dalcroze Research Paper

Fall: 3 units

Candidates in the Dalcroze Certification Program are required to submit a research paper based on their understanding of Dalcroze principles based on their experience and supported by appropriate literature.

57-642 Dalcroze Research Paper

Spring: 3 units

Candidates in the Dalcroze Certification Program are required to submit a research paper based on their understanding of Dalcroze principles based on their experience and supported by appropriate literature.

57-643 Diverse Populations in Inclusive Settings

Fall: 9 units

tba

57-670 Chamber Music: Brass

Fall and Spring: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

57-671 Chamber Music: String Quartet

Fall and Spring: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

57-672 Chamber Music: Woodwind and Mixed

Fall: 3 units

Provides an opportunity for students to play in small ensembles, advised by faculty coaches. The performers will develop effective rehearsal techniques, explore chamber music repertoire, deal with issues of intonation and balance, and arrive at interpretive conclusions that are stylistically sound, yet individualistic and creative. A performance is required each semester.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhhj49to2lilzk2/>)

57-674 Sonatas

Fall and Spring: 3 units

TBA

57-682 Chorus

Fall and Spring: 3 units

tba

57-691 Dalcroze Pedagogy/Practice Teaching

Fall: 3 units

This course gives hands-on experience in applying Dalcroze principles in teaching situations. It is designed for students interested in learning about the teaching of Eurhythmics, general Music Education, and for those considering the Dalcroze Certificate. The class will meet in a three week rotation of two Thursday evenings followed by a Saturday morning with the Preparatory School children's classes.

57-692 Dalcroze Pedagogy/Practice Teaching

Spring

This second semester of a two semester course focuses on applications of Dalcroze pedagogy and practice teaching with upper elementary and middle school age students.

57-911 Music Since 1945

Intermittent: 9 units

A survey of Western art music from WWII to the present, with a focus on compositional techniques, influential trends, and experimental approaches. This course will address total serialism, aleatory music, the rise of technology, minimalism, and soundscape composition, among others. Students will engage with primary sources, close listening, multi-media resources, and secondary sources, and demonstrate competency through varied assessments, including in-class performance activities and presentations.

Course Website: <https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2>
(<https://cmu.box.com/s/8e23hqzsk3e6bj1s7fhj49to2lilzk2/>)

The Marianna Brown Dietrich College of Humanities and Social Sciences

Richard Scheines, Bess Family Dean

Sharon Carver, Associate Dean for Educational Affairs

Joseph E. Devine, Associate Dean for Undergraduate Studies

Kelli Maxwell, Associate Dean for Student Success
www.hss.cmu.edu (<http://www.hss.cmu.edu>)

The Dietrich College of Humanities and Social Sciences consists of undergraduate programs in English, History, Information Systems, Modern Languages, Philosophy, Psychology, Social and Decision Sciences, and Statistics & Data Science, as well as those offered by the Carnegie Mellon Institute for Security and Technology. Dietrich College also offers a student-defined major option, numerous interdepartmental majors, the intercollege Bachelor of Humanities and Arts program, and honors and pre-professional programs.

The college embodies one of the most varied groups of students, faculty, staff and alumni in the Carnegie Mellon University community, all united by a common goal: confronting and solving society's most complex problems. We learn through experience, and we work without silos or walls. Our students and faculty work across traditional boundaries, collaborating with other disciplines to pursue the thrill of discovery. Dietrich College is a place to explore different points of view. And a place to do work that matters.

At Dietrich College, we approach education differently. We mash up the traditional liberal arts with analytical and computational approaches. Beginning in their first year, our undergraduates confront real-world problems like democracy and data, racism or environmental justice through Grand Challenge Seminars (<https://www.cmu.edu/dietrich/students/undergraduate/programs/grand-challenge/>) that are co-taught by faculty from disciplines across the college and university. In addition, students are required to take General Education (<https://www.cmu.edu/dietrich/gened/>) courses tied to specific learning goals. These courses help students to acquire and apply new knowledge and skills that are essential to their careers, citizenship and life. In addition to the required courses, students' schedules also allow for broad exploration of our majors and minors (<https://cms-staging.andrew.cmu.edu/dietrich-2/academics/degrees-majors-minors/>). Experiential learning programs (<https://www.cmu.edu/dietrich/students/prospective/undergraduate/experiential-learning.html>) - like internships, undergraduate research, study abroad and community service - enhance our students' undergraduate education.

Dietrich College students develop deep disciplinary knowledge — but that's just the beginning. Students learn how to work on teams involving many disciplines. The knowledge landscape changes rapidly, and what students learn today may be outdated tomorrow. At Dietrich, students "learn how to learn," discovering how to communicate, think and understand the world in ways that will benefit them for the rest of their lives.

Dietrich College alumni report that the skills they learned while in college have helped them land opportunities in a highly competitive job market. Just as importantly, those skills helped graduates follow their passion and succeed in new endeavors outside a more traditional career path. Among the 90% of the Dietrich College class of 2022 (<https://www.cmu.edu/career/outcomes/post-grad-dashboard.html>) reporting, 94% found employment, entered graduate school or pursued other interests, like volunteering or military service.

Degree and Program Options

Dietrich College offers a wide range of majors and minors. In addition, there are a number of special programs which add breadth and enhance a student's overall experience.

Dietrich College Majors

| Department | Name of Major (Degree Options) |
|---|---|
| Carnegie Mellon Institute for Security and Technology | International Relations and Political Science (B.S.) |
| English | Literature and Culture (B.A.) |
| English | Creative Writing (B.A.) |
| English | Film and Visual Media (B.A.) |
| English | Professional Writing (B.A.) |
| English | Technical Writing and Communication (B.S.) |
| History | Global Studies (B.A.) |
| History | Social and Political History (B.A./B.S.) |
| Interdepartmental (1) | Economics and Politics (B.S.) |
| Interdepartmental (2) | Economics and Statistics (B.S.) |
| Interdepartmental (3) | Environmental and Sustainability Studies (additional major only) |
| Interdepartmental (4) | Ethics, History, and Public Policy (B.A./B.S.) |
| Interdepartmental | Health Humanities (additional major only) |
| Interdepartmental | Information Systems (B.S.) (by admission) |
| Interdepartmental (5) | Linguistics (B.A.) |
| Interdepartmental (6) | Neuroscience (B.S.) |
| Interdepartmental (7) | Psychology and Biological Sciences (B.S.) |
| Interdepartmental (8) | Statistics and Machine Learning (B.S.) |
| Interdepartmental (9) | Statistics and Mathematical Sciences |
| Interdepartmental (10) | Statistics and Neuroscience |
| Interdepartmental | Student-Defined (B.A./B.S.) (by admission) |
| Modern Languages | Chinese Studies (B.A.) |
| Modern Languages | French and Francophone Studies (B.A.) |
| Modern Languages | German Studies (B.A.) |
| Modern Languages | Hispanic Studies (B.A.) |
| Modern Languages | Japanese Studies (B.A.) |
| Modern Languages | Russian Studies (B.A.) |
| Philosophy | Logic and Computation (B.S.) |
| Philosophy | Philosophy (B.A.) |
| Psychology | Cognitive Science (B.S.) |
| Psychology | Psychology (B.A./B.S.) |
| Social and Decision Sciences | Behavioral Economics (B.S.) |
| Social and Decision Sciences | Decision Science (B.S.) |
| Social and Decision Sciences | Policy and Management (B.S.) |
| Statistics and Data Science | Statistics (B.S.) |

Notes:

- ¹ Offered jointly by the Undergraduate Economics Program and the Carnegie Mellon Institute for Security and Technology
- ² Offered jointly by the Undergraduate Economics Program and the Department of Statistics and Data Science
- ³ Offered jointly by the Dietrich College of Humanities and Social Sciences and the Mellon College of Science
- ⁴ Offered jointly by the Departments of History and Philosophy
- ⁵ Offered jointly by the Departments of English, Modern Languages and Philosophy
- ⁶ Offered jointly by the Department of Biological Sciences and the Center for the Neural Basis of Cognition
- ⁷ Offered jointly by the Departments of Psychology and Biological Sciences
- ⁸ Offered jointly by the Department of Statistics and Data Science and the Department of Computer Science
- ⁹ Offered jointly by the Department of Statistics and Data Science and the Department of Mathematical Sciences
- ¹⁰ Offered jointly by the Department of Statistics and Data Science and the Departments of Psychology and Biological Sciences

Additional Majors

Dietrich College students may pursue additional majors and/or minors in the college, as well as in other Carnegie Mellon colleges. An additional major refers to the completion of the requirements for a second major while also completing the requirements for the primary major and degree.

Most Dietrich College majors are also available as additional majors; two (Environmental and Sustainability Studies and Health Humanities) are available **only** as additional majors. Students from outside Dietrich College can pursue additional majors offered by the college, and would be required to complete only those courses in the college's general education program that are prerequisites to courses required for the Dietrich College major in question.

Minors

Minors are like majors in that they consist of coherent programs of study in a department, or across departments. Minors differ from majors in the number of the courses required and in the breadth and depth of the curriculum in the minor's area(s) of study. Dietrich College students can also pursue minors offered and made available by other Carnegie Mellon colleges and departments.

There are two types of minors in Dietrich College: departmental minors, which are housed in a single Dietrich College academic department; and interdepartmental minors, which are sponsored by more than one academic department and administered through the faculty advisor's academic department. The college's minors are available to students from all colleges in the university.

| Department | Name of Minor |
|---|--|
| English | Creative Writing |
| English | Humanities Analytics |
| English | Film and Visual Media |
| English | Professional Writing |
| English | Technical Writing |
| History | Anthropology |
| History | Social and Political History |
| Carnegie Mellon Institute for Security and Technology | Cybersecurity and International Conflict |
| Carnegie Mellon Institute for Security and Technology | International Relations and Political Science |
| Carnegie Mellon Institute for Security and Technology | Military Strategy and International Relations |
| Carnegie Mellon Institute for Security and Technology | Politics and Public Policy |
| Interdepartmental | African and African American Studies |
| Interdepartmental | Environmental and Sustainability Studies |
| Interdepartmental | Gender Studies |
| Interdepartmental | Health Care Policy and Management |
| Interdepartmental | Linguistics |
| Interdepartmental | Neural Computation |
| Interdepartmental | Religious Studies |
| Interdepartmental | Science, Technology and Society |
| Interdepartmental | Sociology |
| Interdepartmental | Student-Defined (by admission) |
| Modern Languages | Applied Multilingual Studies |
| Modern Languages | Arabic Studies |
| Modern Languages | Chinese Studies |
| Modern Languages | French and Francophone Studies |
| Modern Languages | German Studies |
| Modern Languages | Hispanic Studies |
| Modern Languages | Immersive Technologies in Arts and Culture |
| Modern Languages | Japanese Studies |
| Modern Languages | Russian Studies |
| Philosophy | Ethics |
| Philosophy | Linguistics |
| Philosophy | Logic and Computation |
| Philosophy | Philosophy |

| | |
|------------------------------|---|
| Philosophy | Rationality, Uncertainty, and Choice: Formal Methods |
| Philosophy | Societal & Human Impact of Future Technologies |
| Psychology | Cognitive Neuroscience |
| Psychology | Psychology |
| Social and Decision Sciences | Behavioral Economics |
| Social and Decision Sciences | Decision Science |
| Social and Decision Sciences | Policy and Management |
| Social and Decision Sciences | Data Science in Society |
| Statistics and Data Science | Statistics |

Multiple Degrees

"Multiple degrees" is defined as more than one undergraduate degree granted by the university (whether simultaneous or sequential). One diploma is awarded for each degree; each degree has one primary major associated with it, and the possibility of an additional major and/or minor.

Dietrich College undergraduate students who wish to earn an additional undergraduate degree with a primary major also from Dietrich College must:

- Satisfy all requirements for the primary major to be linked to the additional degree.
- Complete at least 90 units beyond the total number of units required for the first degree. If the major associated with the additional degree requires less than 90 units, the student would earn additional elective units to reach the 90-unit minimum. If the major associated with the additional degree requires more than 90 units, the student would perform exceed the 90-unit minimum in order to fulfill all of the requirements for the additional degree's primary major.
- Comply with Carnegie Mellon's Statute of Limitations Policy: All units required for an undergraduate degree, whether earned in residence, transferred from another institution or granted via advanced placement, must have been earned within eight (8) years prior to the date on which the degree is granted.

Non-Dietrich College undergraduate students at Carnegie Mellon who wish to earn an additional undergraduate degree with a Dietrich College primary major must complete all of the requirements listed above, plus any portion of the Dietrich College general education program not already fulfilled by prior undergraduate course work.

Bachelor of Arts & Bachelor of Science

Some Dietrich College majors lead to a Bachelor of Arts (B.A.) degree and others lead to a Bachelor of Science (B.S.) degree option. In some majors students may choose between a B.A. and a B.S. degree. B.A. degree programs usually require less course work in technical and/or quantitative disciplines, and more depth and breadth in various humanities and social science fields, and (in some cases) the arts. In contrast, B.S. degrees are offered in majors requiring more technical, quantitative or scientific competencies.

Dietrich College General Education Program

*For students entering prior to Fall 2021, click here (<https://www.cmu.edu/dietrich/gened/previous-curriculum/>) for the catalog description of the General Education Requirements.

For students entering Fall 2021 and later*

www.hss.cmu.edu/gened (<https://www.cmu.edu/dietrich/gened/>)

The Dietrich College General Education curriculum (GenEd) provides robust training and knowledge that complements and strengthens the skills learned in a student's primary major. The GenEd program contains several unique features including: 1) the anchoring of the curriculum on an explicit set of measurable learning outcomes; 2) a focus on creative multi and interdisciplinary approaches to complex problems; 3) the integration of instruction in core competencies like writing and data science across the entire four-year curriculum; 4) ensuring holistic advising is available to every Dietrich student; 5) the expansion of experiential learning opportunities through research and creative inquiry, paid internships opportunities, study abroad, and community engagement; and 6) the commitment to iterative program-level assessment that includes direct measures of student learning.

The GenEd is built on the foundation of 15 high level learning areas and nearly 50 specific student learning outcomes that guide the program. More

information about the learning areas can be found on our GenEd website (www.cmu.edu/dietrich/gened (<http://www.cmu.edu/dietrich/gened/>)).

Curriculum Requirements

The GenEd curriculum requirements total just above one third of a student's overall degree requirements:

| Category Type | Units Required |
|--------------------------------|----------------|
| Foundations | 54 |
| Disciplinary Perspectives | 42 |
| Special Seminars and Topics | 27 |
| TOTAL GENERAL EDUCATION | 123 |

Course Categories

1. Foundations (54 units total)

There are six (6) foundations requirements, designed to teach both competencies that transcend disciplinary boundaries and the foundational knowledge and skills particularly important for Dietrich College students to acquire.

| Required in Year 1 | Units Required |
|--------------------|----------------|
| Communication | 9 units |
| Data Analysis | 9 units |

The Communication requirement may be satisfied through one of the following options:

- 76-101 (Interpretation and Argument) or 76-102 (Advanced First-Year Writing)
- Choose 2 mini courses: 76-106 (Writing about Literature, Art, and Culture), 76-107 (Writing about Data), or 76-108 (Writing about Public Problems).

The Data Analysis requirement must be satisfied through the completion of 36-200 (Reasoning with Data). Advanced Standing (AP, IB, Cambridge, Transfer) credit will be accepted for this requirement.

| Required in Years 1-3 | Units Required |
|----------------------------------|----------------|
| Computational Thinking | 9 units |
| Contextual Thinking | 9 units |
| Intercultural and Global Inquiry | 9 units |
| Scientific Inquiry | 9 units |

A list of courses for each of the above requirements can be found on the GenEd website (<http://www.cmu.edu/dietrich/gened/>).

2. Disciplinary Perspectives (42 units total)

There are five (5) disciplinary perspectives requirements, designed to provide a broad reflective understanding of disciplines both within and outside of the College.

| Required in Year 1 | Units Required |
|--------------------|----------------|
| Humanities | 9 units |
| Social Sciences | 9 units |

| Required in Years 1-4 | Units Required |
|------------------------------|----------------|
| The Arts | 9 units |
| Logic/Mathematical Reasoning | 9 units |

Required in Years 1-4 (6 units in one of the following three disciplines):

Design
Business
Engineering

A list of courses for each of the above requirements can be found on the GenEd website (<http://www.cmu.edu/dietrich/gened/>).

3. Special Seminars and Topics (27 units total)

The Special Seminars and Topics offer opportunities for students to engage in high impact learning practices to ensure transformative and integrative learning.

| Required in Year 1 | Units Required |
|-------------------------|----------------|
| Grand Challenge Seminar | 9 units |

| Required in Years 1-3 | Units Required |
|-----------------------|----------------|
| Equity and Justice | 9 units |

Required in Year 4

Senior Capstone*

Units Required

9 units

* For undergraduates whose chosen major does not require an individual or small group capstone project, the General Education's senior capstone is strongly recommended, but not required. To fulfill the 9-units, those students should first explore capstone options with their academic advisor and Dietrich's capstone coordinator before proposing an alternative requirement that showcases their best senior year work.

A list of courses for each of the above requirements can be found on the GenEd website (<http://www.cmu.edu/dietrich/gened/>).

College Services and Programs

The educational programs in Dietrich College are complemented by a number of services, special programs, centers, and computing facilities.

Dietrich College Senior Honors Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*

Location: Baker Hall 154F

www.hss.cmu.edu (<http://www.cmu.edu/dietrich/undergraduate/programs/shp/>)

From its inception in 1982, the Dietrich College senior honors program (<http://www.cmu.edu/dietrich/undergraduate/programs/shp/>) has provided outstanding undergraduate students with the opportunity to work individually with faculty members throughout the college on original research and creative projects. The honors program is a senior-year program. Admission is based on achievement of a cumulative QPA of at least 3.50 in one's major and 3.25 overall, endorsement of a thesis proposal by the faculty member who will serve as thesis advisor, and department head approval. Honors students enroll in an honors thesis course sequence for both semesters of the senior year (9 units per semester). Upon successful completion of the honors thesis, a student qualifies for graduation with Dietrich College Honors, and will have this designation as well as the thesis title noted on the final transcript.

Students have found the honors program to be a challenging and enriching experience in allowing for focused, individualized work on a sustained independent project. In the opportunity it provides to demonstrate one's capacity for independent and original work, the senior honors program experience helps significantly in developing the ability to present one's intellectual or creative self to others, including prospective employers or graduate and professional school programs.

The Honors Research Scholarship Program (<http://www.cmu.edu/dietrich/undergraduate/programs/dhfp/>) is an optional component for students who have applied and been accepted into the college's Senior Honors Program. Scholars spend the summer before their senior year undertaking early-stage research and development of their thesis topics. Financial support through a stipend and related funds for research-related expenses allows scholars to apply themselves full-time to their projects during these summer months. This in turn enables scholars to build a strong foundation and momentum for their honors thesis as the fall semester of the senior year gets underway, and ultimately leading to completion of the project by the end of the spring semester. Students apply for this scholarship program in the spring of the junior year, simultaneous with submission of an application and thesis project proposal for the Dietrich College Senior Honors Program.

Community Engagement Fellowship

Kimberly Piatt, Director of Experiential Learning

Location: Baker Hall 160

<https://www.cmu.edu/dietrich/students/undergraduate/programs/community-engagement-fellowship/index.html> (<https://www.cmu.edu/dietrich/students/undergraduate/programs/community-engagement-fellowship/>)

The Dietrich College Community Engagement Fellowship was launched in Fall 2022 and provides students with the opportunity to develop their leadership skills while also learning how to create positive change in their communities. The program spans 5 semesters - Fall, Spring, Summer, Fall, Spring during which students complete a combination of coursework and experiential learning activities. The program curriculum includes:

- 66-148 (3 Units): Fall Semester: Introduction to Community Engagement
- 66-214 (6 Units): Spring Semester: Connecting with the Pittsburgh Community
- 66-300 (6 Units): Fall Semester: Using Collective Leadership to Pursue Community Goals

- 66-4XX (6-9 Units): Spring Semester: Community Engagement Fellowship Capstone Course

At the end of the fellowship, students will engage in a capstone project during which they connect their specific area of passion to what they have learned through the fellowship. This project is flexible and will depend on the student. Students will be expected to present their capstone project to a panel of stakeholders.

Students in the fellowship receive exclusive access to courses and are able to build fruitful relationships with a cohort of peers and community leaders. Students also receive \$3,000 to support their involvement in the community. Additional opportunities, like board membership, conference attendance and others are also offered as part of the experience.

The application process for each 12-student cohort occurs in the Spring. Any student with a primary major in Dietrich or those pursuing a BHA degree may apply. Students should be in good academic standing but students may request an exception by speaking with the Director of Experiential Learning. Students interested in applying must have at least 2 years as an undergraduate student remaining so that they are able to complete the full sequence of courses.

Humanities Scholars Program

Therese Tardio, *Director*

Location: Posner Hall 252

www.cmu.edu/dietrich/hsp (<https://www.cmu.edu/dietrich/hsp/>)

Since 2001, the Humanities Scholars Program (HSP) has provided an opportunity for students to use the tools of humanistic inquiry to describe, analyze and engage with the world. While the university is broadly known for its technological prowess and its interdisciplinary ethos, the humanities at Carnegie Mellon are also a vital part of the intellectual ecology of the university: humanities faculty have joint appointments in virtually every other college, school, or department on campus, and they collaborate across disciplines in the arts, engineering, and the sciences.

At Carnegie Mellon, the Humanities Departments (English, Modern Languages and Cultures, History, and Philosophy) are integrated into the university's broader academic environment to an unprecedented extent. Interdisciplinary work with technological, scientific, and artistic programs across campus are frequently the nexus by which new scholarly approaches and programs emerge in a changing intellectual landscape. For example, philosophers and computer scientists develop models of artificial intelligence, historians and engineers record emerging environmental patterns and solutions, linguists and cultural theorists help demarcate the patterns of recorded thought.

The Humanities Scholars Program invites a small cohort of students – usually no more than twenty – to work together to investigate the issues that confront contemporary society. The director helps select candidates in collaboration with the Academic Advisory Center and its Associate Dean during their first year at Carnegie Mellon, and they then start the program during their sophomore year with a series of two academic seminars that draw upon the expertise of humanities faculty and the broader intellectual depth of the campus. The Humanities Scholars Program sponsors campus-wide programs, often in collaboration with other programs, such as the Center for Diversity and Inclusion, the College of Fine Arts, and the Institute for Politics and Strategy. The Humanities Scholars experience culminates in a student's senior year with a capstone project. Students have the ability to use the resources of the program to further their own research, engage with the community, and develop their own areas of expertise. The program is supported by endowment funding from the university as well as from the Arthur Vining Davis Foundations in order to support outstanding undergraduate research in the humanities at the university.

For further information, students should contact the Director, Therese Tardio tardio@andrew.cmu.edu

Quantitative Social Science Scholars Program

Mark Patterson, PhD *Director*

Location: Porter Hall 223 B

www.cmu.edu/hss/qsss (<http://www.cmu.edu/hss/qsss/>)

The Quantitative Social Science Scholars Program (QSSS) offers a unique opportunity in undergraduate education at Carnegie Mellon. In recent years, advances in computing power, increasingly powerful models of human behavior, and the exponential growth of data sets recording human economic and social activity have created exciting new possibilities for entrepreneurs, policymakers, and scholars seeking insight into human social behavior. Firms throughout the economy can now use data analytics to identify new markets, avoid errors, and improve efficiency. Policymakers can use the same techniques to shape the direction and expand the impact of social policies designed to promote the public good. Social scientists

can also use these techniques to create a broader and deeper scientific understanding of human behavior that serves as the foundation upon which both entrepreneurs and policymakers can build.

The QSSS program is designed to help outstanding undergraduates impact society through the use of these techniques. It does so by laying out a structured program of training in advanced quantitative techniques that can be broadly applied across a range of social science disciplines and topics. Students combine this methodological training with more traditional coursework in a Dietrich College major of their choice. The program equips students to undertake sophisticated analysis of their own, and features an integrative senior thesis project that applies their methodological training to a research question of their own choosing. Students may apply for entry to the QSSS program during the spring of the first year. Applications consist of a student transcript, and statement of interest.

The QSSS program is not a freestanding major or a minor, per se. It is a program designed to be taken in conjunction with a social sciences or humanities major in Dietrich College. In addition to two seminars completed in the sophomore year, students complete coursework in a concentration area of their choice, selecting specialization in econometrics, statistics and regression, choice modeling, quantitative policy analysis, computational modeling, or psychometrics and measurement. Concentration areas typically consist of 3-4 courses each. Finally, in the senior year, students complete a two-semester senior thesis paper working in collaboration with a faculty member of their choice.

The program recruits students with a range of interests across the social sciences to create a cohesive interdisciplinary learning community. Majors that could fit well with this program include (but are not limited to) economics; behavioral economics, policy and organizations; decision science; policy and management; international relations and politics; statistics; statistics and machine learning.

Student-Defined Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
Location: Baker Hall 154

www.cmu.edu/dietrich/undergraduate/student-defined-majors.html (<http://www.cmu.edu/dietrich/undergraduate/student-defined-majors.html>)

For students whose educational goals cannot be as adequately served by the curricula of existing programs, the college provides the opportunity to self-define a major or minor. The procedure for establishing such a major centers on a written proposal, submitted to the college dean's office. This proposal consists of two parts:

Program description and rationale: A description of the components of the proposed program of study; a presentation of the objectives of the program of study, why it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing programs.

The curriculum: Presentation of a complete outline of all courses that will comprise the requirements for the major or minor, categorized according to that component of the major program to which each belongs (e.g., mathematics prerequisites; research methods; theoretical perspectives; etc.), and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken). The minimum requirement for graduation is, as with all majors in the college, 360 units of credit.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability within the context of the college and university offerings. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

As with all other Dietrich College majors, Dietrich College student-defined primary majors must fulfill all of the college's general education requirements.

Student Success & Experiential Learning

Student Success

Kelli Lammie Maxwell, *Associate Dean for Student Success*

Location: Baker Hall 160

Dietrich College is committed to ensuring students have the programs, opportunities, and resources necessary to reach their personal and academic goals. We view a college education as more than a major or job training, but as an opportunity for a broad-based development of mind and

character, and as an opportunity to build a strong foundation for students' lives and careers. We work to ensure equitable and transparent policies and procedures for students as well as opportunities for students to connect with faculty and staff throughout the College. Through the Academic Advisory Center and major departments, we provide four-year holistic advising that assists students with academic choices, career development, opportunities outside of the classroom, as well as physical and mental well-being; and through Experiential Learning, we also offer a number of Dietrich College-specific and university-wide opportunities and programs to ensure students have access to high-impact experiences outside of the classroom, like internships, community service, undergraduate research, and study abroad.

Academic Advisory Center

Andrew Ramey, *Director of Advising*

Location: Baker Hall 160

<https://www.cmu.edu/dietrich/advisory-center/>

The Dietrich College of Humanities and Social Sciences Academic Advisory Center (AAC) is responsible for advising and monitoring the progress of undeclared Dietrich students prior to and through major declaration. The AAC provides an accessible, welcoming environment where students can seek information and advice, and counsel about planning semester course schedules, fulfilling the college's general education program requirements, and exploring the various majors and minors available. Advisors help students learn to successfully navigate the Carnegie Mellon environment, become self-motivated and independent learners, and make viable, informed and confident academic and personal decisions. This kind of relationship is vital to a student's ability to progress, grow and thrive in a new and demanding educational environment. Additionally, the AAC serves as the office of student records for Dietrich College. Acting on behalf of the College Council, the Center Director oversees adherence to university and college academic policies and procedures.

Experiential Learning

Kimberly Piatt, *Director of Experiential Learning*

Location: Baker Hall 160

<https://www.cmu.edu/dietrich/students/prospective/undergraduate/experiential-learning.html>

Experiential Learning occurs when a student participates in an opportunity that allows them to apply what they are learning in the classroom to a real-world context. This may include internships, undergraduate research with a faculty member, community engaged learning, study abroad or work-based learning through structured consulting projects. All Dietrich College students are strongly encouraged to complete at least one high-quality Experiential Learning activity during their time at Carnegie Mellon University. To support these efforts, the college has a variety of resources available which can be found online (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/experiential-learning/>), by talking to an academic advisor or by connecting with the Director of Experiential Learning.

Study Abroad Funding

Funding support for study and travel abroad is available through several sources, many administered by the university, and many others available externally. The Office of International Education is the first place to look for information about funding opportunities for study or travel abroad.

Two programs housed in Dietrich College are part of this portfolio of study/travel abroad funding programs:

The Department of Modern Languages Undergraduate Study Abroad Scholarship Program (<https://www.cmu.edu/dietrich/modlang/academics/study-abroad/>) offers scholarships to undergraduate students for accredited study abroad programs, limited in some instances to students who are majoring or minoring in a modern language and in other instances to students studying a particular language. Scholarship funds can be applied to tuition, room, board, airfare to the host country and book expenses.

The Dietrich College Study/Travel Abroad Grant Program (<https://www.cmu.edu/dietrich/students/undergraduate/resources/study-abroad/study-abroad-grant-program.html>) provides support for both traditional study abroad programs, and for non-study abroad experiences such as service learning opportunities, internships, research, or conference travel.

The program uses a rolling application schedule for its grant funds, and works closely with the University's Office of International Education in advising students about eligible programs and potential funding sources, completing applications, and preparing for the intended program abroad experience.

Dietrich College Internship Opportunity Grants

www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html (<https://www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html>)

Dietrich College encourages students to pursue interesting and professionally relevant internship opportunities. Often, however, the very positions that provide students with the most challenging and high-quality work experiences are either unpaid or modestly paid. To help compensate students for taking on work experiences that will be invaluable in helping them define and move toward their career goals, the Dietrich College Internship Opportunity Grant Program seeks to make it more financially possible for students to take advantage of such worthwhile internship opportunities.

Undergraduates with primary majors in Dietrich College, as well as BHA students, are eligible and encouraged to apply. Current sophomores and juniors receive preference. NOTE: Graduating seniors are not eligible.

Students are expected to find their own internships. There are many resources available to help in finding internships, including the Career and Professional Development Center's internship database. Preference for grants is given to students who find positions in the public sector or non-profit agencies.

For more information, including application timeline and instructions, see: www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html (<https://www.cmu.edu/dietrich/students/undergraduate/resources/internship-opportunity-grants.html>)

Dietrich College Pittsburgh Summer Internship Program

www.cmu.edu/dietrich/students/undergraduate/programs/summer-internship-program.html (<https://www.cmu.edu/dietrich/students/undergraduate/programs/summer-internship-program.html>)

The Dietrich College Pittsburgh Summer Internship Program is designed for undergraduates who have not yet had a meaningful internship and are seeking to engage and connect with non-profit organizations and start-ups in Pittsburgh.

Pittsburgh-area companies and organizations host Dietrich College students for a 10-12 week summer internship, working around 20 hours per week. Students that secure an internship through the program receive a \$3,000 stipend provided by the college.

Because of the program's strong local focus, all interns are required to work in the City of Pittsburgh during the summer, not remotely, so as to ensure that they get the most out of this experience. Participants are also required to attend professional development workshops hosted by the program and focused on a variety of topics including communication, professional etiquette, giving/receiving feedback, and networking.

Internships-for-Credit

An internship-for-credit is a supervised, professional work experience with clear links to a student's academic program, performed primarily or totally outside of a regular course structure, and for which a student earns academic credit. Students doing an internship for academic credit must be registered through the academic department of the faculty member supervising the internship, and must register for the internship course during the term (including the summer) when the internship work is being performed. There is no additional tuition charge for credit-bearing internships that are taken during the academic year as part of a normal, full-time course load. Students registered for internships during the summer will be billed for tuition at the per-unit rate set by the university.

To receive academic credit, the internship:

- must conform to the criteria for internships-for-credit (<https://www.naceweb.org/internships/>) set by the National Association of Colleges and Employers and the U.S. Department of Labor
- requires the involvement of a Carnegie Mellon faculty sponsor and an on-site supervisor in the design, oversight and evaluation of the internship;
- must include regular or periodic meetings between the student, the faculty sponsor, and/or the internship site supervisor to monitor progress and offer feedback on student performance;
- requires an end-product for submission to the faculty sponsor. This usually takes the form of a paper, but may also include a presentation, or some other approved form;

- may be taken for a regular letter grade or pass/no credit as per the policy of the department through which the internship course is taken. With department approval, the internship may be counted toward program requirements.
- can vary from 3-18 units in any one semester, and is limited only by the college rule of a maximum of 27 units of internship credit that can be applied to graduation requirements.

Additional policies and practices regarding internships-for-credit vary among the college's academic departments. Departments are not obligated to allow internship credit for its majors, and are free to determine whether an internship may be used to fulfill requirements or serve only as an elective. An internship-for-credit is a graded experience. Each department will determine appropriate criteria for the grade if an internship is approved for credit.

Credits for internships are generally earned according to the following scale:

- 9 units = the equivalent of 1 day (9-12 hours) per week during a full semester
- 18 units = the equivalent of 2 days (12-20 hours) per week during a full semester

A Dietrich College student may not earn more than 18 units of internship credit during a single semester or count more than 27 units of internship credit toward fulfillment of graduation requirements.

In instances when the internship sponsor requires that a student receive academic credit from the home institution, the student should contact the Dietrich College Director of Experiential Learning for information and advice about available options.

Carnegie Mellon University Washington Semester Program

Audrey Kurth Cronin, *Director, Trustees Professor of Security and Technology*
acronin@andrew.cmu.edu, Posner Hall 385A

Emily Half, *Deputy Director*
ehalf@andrew.cmu.edu; 412-268-7082, Posner Hall 391

Ashley Barnes, *Washington Program Manager*
ashleyba@andrew.cmu.edu; 202-608-8316, 100 Maryland Ave NE, Suite 510, Washington, DC 20002

www.cmu.edu/cmist (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/www.cmu.edu/cmist/>)

The Carnegie Mellon University Washington Semester Program (CMU/WSP), sponsored by the Carnegie Mellon Institute for Security and Technology (CMIST), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Full-time undergraduates from any course of study at the university may participate in the program. Students earn forty-eight units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty.

From embassies to nongovernmental organizations, think tanks to advocacy organizations, government agencies to congressional offices, and consulting firms to media outlets, Washington, DC, is the center for many political, international relations, and public policy activities. Students in the program come into direct contact with political, business, and community leaders and learn about the most pressing policy issues of the day.

Through this experiential learning program, CMU/WSP participants develop professional and networking skills, explore how coursework connects to the real world, learn to give and receive constructive feedback in the workplace and classroom, and intentionally reflect on their learning and growth. Every CMU/WSP student is paired with a Washington, DC-based alumni mentor to share career advice and tips about life in DC. CMIST also sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and policy decision making.

Students should contact the Washington Program Manager to discuss the specifics of the program and the deputy director to discuss how the CMU/WSP may fit into their curriculum. Students who participate in the CMU/WSP may qualify for a minor in Politics and Public Policy (<https://www.cmu.edu/ips/undergraduate%20degrees/minors/minor-in-politics-and-public-policy.html>).

Applications (<https://www.cmu.edu/ips/washington-dc-semester-program/application.html>) are accepted on a rolling admission basis with a final deadline of October 1, for spring semester participation, and March 1, for fall semester participation.

Curriculum

Students who are admitted to the CMU/WSP will be enrolled in the 3 unit (pass/no pass) course 84-215 Tomorrow's Professionals in the mini semester directly preceding their time in DC.

During the semester in Washington, all students enroll in the following core seminars (24 units).

Core Seminars

| | | |
|--------|-----------------------------|----|
| 84-360 | CMU/WSP: Internship Seminar | 12 |
| 84-450 | Policy Seminar | 6 |
| 84-451 | Policy Seminar II | 6 |

Students must enroll in 24 units from the below list of elective seminars. Offerings vary by semester.

Elective Seminars

| | | |
|--------|--|----|
| 84-313 | International Organizations and Law | 6 |
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking | 6 |
| 84-334 | The History and Practice of Economic Statecraft | 6 |
| 84-335 | US China Relations | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality | 12 |

| | | |
|--------|---|----|
| 84-337 | Biomedical Science Research, Policy, and Governance | 6 |
| 84-339 | Seminar in Public Policy Research | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington | 12 |
| 84-348 | Advocacy, Policy and Practice | 6 |

Academic Standards, Regulations and Protocols

Graduation Requirements

Eligibility for graduation in Dietrich College requires that a student:

1. satisfy all Dietrich College general education requirements,
2. satisfy all course requirements in a Dietrich College primary major,
3. achieve a cumulative quality point average of at least 2.00 for all courses taken (or, alternatively, for all courses taken after the 1st year),
4. earn at least 360 units with a minimum of 180 units taken at Carnegie Mellon University,
5. be recommended (certified) for graduation by the faculty of the student's primary major department,
6. meet all financial obligations to the university, and
7. qualify for graduation within eight years of matriculation as a degree candidate.

The college reserves the right to modify these academic standards, regulations, and protocols.

Graduation with University Honors

Dietrich College students who achieve an overall QPA of at least 3.50 will be recommended for graduation with University Honors.

Graduation with College Honors

Students who successfully complete a senior honors thesis under the auspices of the Dietrich College Senior Honors Program qualify for graduation with Dietrich College Honors.

Double-Counting Courses

Double-counting refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. While the college encourages study in complementary areas where majors and minors frequently share requirements in common, it also wants to keep clear the meaning and integrity of the labels "major" and "minor." To preserve the integrity of these definitions, double-counting is permitted in Dietrich College on a very limited basis, and only in those instances when the course(s) in question represent only a small portion of the second program.

The college and its departments have developed program-specific guidelines for this practice that appear throughout the Dietrich College section of this catalog, and particularly in the case of major and minor programs that students frequently pursue in combination.

Dietrich College Credit Policy for Non-Carnegie Mellon Courses

The following policies govern the practice of Dietrich College undergraduates taking courses elsewhere and requesting that credits for these courses transfer to their Carnegie Mellon University academic record. Courses taken elsewhere will be considered for transfer credit if the institution offering them is fully accredited, and if the courses in question are judged to be acceptable for the purposes proposed by the student.

Approval

Dietrich College undergraduates who wish to take courses at another institution and request that credits for these courses transfer to their Carnegie Mellon University record should familiarize themselves with Dietrich's transfer credit policies (<http://www.cmu.edu/dietrich/advisory-center/transferring/cmu-course-credit.html>). Students must receive approval before taking any courses at another institution in order to

guarantee that they will receive transfer credit upon successful completion of the course(s).

Limits

Undergraduate students may a maximum of 180 units and transfer these back for credit toward the Carnegie Mellon degree.

Exceptions

These limits do not apply to courses and credits taken through cross-registration via the Pittsburgh Consortium for Higher Education (PCHE), and approved study abroad or exchange programs. Exceptions to these restrictions may be made only by way of written petition to the Dietrich College Office of Undergraduate Studies.

In general, approved courses taken elsewhere will transfer as elective credit, unless otherwise approved by the college or relevant academic department.

Grades

Courses taken elsewhere must be taken for a regular letter grade (not pass/no credit or pass/fail) in order to be granted transfer credit. As a matter of college policy, Dietrich College students must earn a final grade of at least "C" in order for the credit to transfer. A "C-" grade is not transferable when its equivalency is below a 2.00 on a 4.00 scale, or 70%. In cases when courses proposed for transfer credit are to apply to requirements in a Dietrich major or minor program, the program's department may set a higher minimum final grade in order for credit to transfer. Only units, not grades, transfer for courses taken elsewhere, and thus do not affect a student's Carnegie Mellon QPA. Ungraded or pass/fail courses may receive credit if the transcript key indicates that the mark represents a grade of C or better. Students should consult their academic advisor before taking courses at another institution for which they want to receive transfer credit.

External Transfer Students

For students entering Carnegie Mellon and Dietrich College as external transfers, the same 180-unit limit on transfer credit applies. A candidate for the bachelor's degree must complete a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of coursework at Carnegie Mellon. If a degree has already been obtained at another institution, courses that count toward that degree may not be used again as transfer credit toward a Carnegie Mellon University undergraduate degree.

Internal Transfer Students

This policy applies retroactively to students who enter Dietrich College through internal transfer. Courses previously approved for transfer credit may be re-evaluated for consistency with relevant Dietrich College or program policies and standards.

Students on Academic Suspension

Subject to the college's policy limiting transfer course credit, students on academic suspension from Dietrich College will be permitted to receive transfer credit for no more than three non-CMU courses per semester while on suspension. Approval to take these courses for transfer credit is to be obtained in advance.

While on academic suspension, students are considered to be on a mandatory "leave of absence" and are governed by College and University policies concerning leaves of absence (<https://www.cmu.edu/policies/student-and-student-life/student-leave.html>).

Course Overloads

Overloading is defined as taking more than the equivalent of five full-semester courses in one semester; for Dietrich College students this usually means registering for more than 50 units in one semester.

Eligibility to overload is defined as having a QPA of at least 3.25 in the last completed semester, based on a course load of at least 45 factorable units, and a current cumulative QPA of at least 3.00. Students new to the college and university (i.e., first-year students and new external transfer students) may not overload during their first Carnegie Mellon semester.

Eligibility to overload based on QPA does not automatically allow the student to register for an overload. Rather, students must complete an overload petition, and meet with their primary academic advisor to discuss the proposed overload. If approved, the academic advisor will increase the student's unit maximum for the relevant semester.

The first opportunity to register for a course overload is after registration week for the proposed overload semester. Registration week for the spring

semester is usually the third week in November; for the fall semester, it is usually the third week in April. Consult the official university academic calendar for the exact dates.

If as a result of final grades for the current semester a student approved to overload for the next semester falls below the QPA overload eligibility criteria, the academic advisor may withdraw the overload permission. Students thus affected are responsible for resolving this in consultation with their academic advisor.

Physical Education and Stuco* Courses

A maximum of nine units of credit for any combination of Physical Education (69-xxx) and Stuco (98-xxx) courses may be counted as credit toward graduation requirements. Physical Education and Stuco courses are not included when calculating a student's QPA or when calculating units to determine eligibility to carry a course overload.

*Stuco (<http://www.cmu.edu/stuco/>) refers to "student-led courses" — i.e., courses designed by students, and approved to be offered for academic credit.

Internships-for-Credit

An internship-for-credit is a supervised, professional work experience with clear links to a student's academic program, performed primarily or totally outside of a regular course structure, and for which a student earns academic credit. Students doing an internship for academic credit must be registered through the academic department of the faculty member supervising the internship, and must register for the internship course during the term (including the summer) when the internship work is being performed. There is no additional tuition charge for credit-bearing internships that are taken during the academic year as part of a normal, full-time course load. Students registered for internships during the summer will be billed for tuition at the per-unit rate set by the university.

To receive academic credit, the internship:

- must conform to the criteria for internships-for-credit (<https://www.nacweb.org/about-us/advocacy/position-statements/position-statement-us-internships/>) set by the National Association of Colleges and Employers and the U.S. Department of Labor
- requires the involvement of a Carnegie Mellon faculty sponsor and an on-site supervisor in the design, oversight and evaluation of the internship;
- must include regular or periodic meetings between the student, the faculty sponsor, and/or the internship site supervisor to monitor progress and offer feedback on student performance;
- requires an end-product for submission to the faculty sponsor. This usually takes the form of a paper, but may also include a presentation, or some other approved form;
- may be taken for a regular letter grade or pass/no credit as per the policy of the department through which the internship course is taken. With department approval, the internship may be counted toward program requirements.
- can vary from 3-18 units in any one semester, and is limited only by the college rule of a maximum of 27 units of internship credit that can be applied to graduation requirements.

Additional policies and practices regarding internships-for-credit vary among the college's academic departments. Departments are not obligated to allow internship credit for its majors, and are free to determine whether an internship may be used to fulfill requirements or serve only as an elective. An internship-for-credit is a graded experience. Each department will determine appropriate criteria for the grade if an internship is approved for credit.

Credits for internships are generally earned according to the following scale:

- 9 units = the equivalent of 1 day (9-12 hours) per week during a full semester
- 18 units = the equivalent of 2 days (12-20 hours) per week during a full semester

A Dietrich College student may not earn more than 18 units of internship credit during a single semester or count more than 27 units of internship credit toward fulfillment of graduation requirements.

In instances when the internship sponsor requires that a student receive academic credit from the home institution, the student should contact the Dietrich College Associate Dean for Undergraduate Studies for information and advice about available options.

Dietrich College Dean's Honor List

Each semester the college recognizes those students who have attained outstanding semester quality point averages by naming them to the Dietrich College dean's honor list.

Students who complete at least 45 factorable units and attain a semester QPA from 3.50 through 3.74 are named to the Dean's List, with Honors; if the semester QPA is 3.75 or higher, students are named to the Dean's List, with High Honors.

Students who complete at least 36 or up to 44 factorable units and attain a semester QPA of 3.75 or higher are named to the Dean's List, with Honors.

In addition, it is generally the case that students are not eligible for the dean's list who receive one or more "Incomplete" grades at the time when final semester grades are recorded.

Transferring into Dietrich College

Undergraduate students in other Carnegie Mellon colleges who wish to transfer (<http://www.cmu.edu/hss/advisory-center/transferring/transfer-in.html>) to Dietrich College apply through the college's Academic Advisory Center (<https://www.cmu.edu/dietrich/advisory-center/>), located in Baker Hall 160. If approved, the transfer is into the college first and then into a primary major. Decisions regarding transfer requests will be based on evidence of adequate prior academic performance and on the applicant's prospects for success in the college and intended major.

The earliest point when undergraduates are considered for transfer into Dietrich College is after mid-semester grades are available in the second semester of the first year. Students interested in transferring to Dietrich College should begin the process well before the course registration period for the upcoming semester. Prior to submitting a transfer application, students are encouraged to meet with representatives in the department where they are hoping to pursue a primary major.

Course Failures and Course Repetitions

Students who fail a required course must repeat and pass it (or take and successfully complete another approved course that fulfills the requirement). If a failed course is a prerequisite to more advanced course work within a particular course sequence, the failed course must in general be repeated before moving on to the higher level course. **Exception:** Dietrich College students who do not successfully complete their first-year seminar will be registered for another first-year seminar where space is available.

Failed courses that are repeated and passed, or courses that are passed but repeated in order to obtain a higher grade, remain on the student's record and are included in calculating the student's QPA. Students who repeat a course that they have already passed will not be able to apply the second set of units for the course toward graduation requirements.

Academic Actions

In order to maintain good academic standing, Dietrich College students must attain at least minimum quality point averages for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing their degree requirements. Minimum quality point averages for good academic standing are 1.75 in the first year and 2.00 thereafter. "Adequate progress towards graduation" generally means that students are successfully completing 36-52 units per semester so that at the end of eight semesters they will have accumulated the minimum of 360 units required for graduation, have a cumulative QPA of at least 2.00, and fulfilled all college General Education and primary major course requirements.

When a student fails to meet minimum performance criteria, it normally results in an "academic action." Depending on the circumstances, one of the following actions is taken: academic warning, academic probation, continued probation, suspension, or drop.

Academic Warning

Academic Warning serves to alert the student that the college is concerned about one or more actions they have taken or have failed to take despite meeting the college's minimum QPA threshold to maintain good standing. A student receives an academic warning when they meet any of the following criteria: repeatedly failing to attain minimum-level passing grades in prerequisite courses; earning a QPA between a 1.75 and a 1.99 in the first year; failing to complete the first-year general education requirements by the end of the student's fourth semester; failing to complete C@CM by the end of the first semester; falling off pace to graduate in 8 semesters;

failing to make sufficient progress through their declared primary major; or the general education program; having two consecutive semesters failing to complete a minimum of 36 units per semester; receiving multiple Incomplete grades in a semester; receiving Incomplete grades over two consecutive semesters; or taking leaves of absence in each of two consecutive semesters.

Academic Probation

A student is placed on academic probation when performance fails to meet the minimum standard. The term of academic probation is one semester, and signifies to the student the college's insistence that academic performance return to at least the minimum acceptable level, and concern that a student has failed to do so. A student is removed from academic probation and returned to good academic standing when both the semester and cumulative quality point averages meet at least the stated minimum, and when adequate progress toward completing degree requirements is being made. A student who has had one semester on probation and is not yet meeting minimum requirements but is making significant progress in this regard may be continued on academic probation.

Academic Suspension

Academic suspension is the usual action taken when a student fails to meet the minimum semester or cumulative requirements for two consecutive semesters. In general, a first-year student will be suspended if the semester and overall QPAs are below 1.75; for sophomores, juniors, and seniors, if these are below 2.00. Failure to maintain adequate progress toward graduation may also be a contributing factor in such decisions.

The minimum period of academic suspension is normally two semesters (not including summer), during which a student on academic suspension is expected to reflect on the circumstances leading up to the suspension, identify the issues that prevented them from achieving academic success, and take actions that address these issues and demonstrate sufficient readiness to return to the university and successfully resume their studies. These actions could include a work or internship experience, academic course work at another college or university, and/or other supportive services as appropriate.

Midway through the semester before a suspended student is eligible to return to the university, the student will be contacted via email by the Associate Dean for Academic Success or designee with detailed instructions about the process for requesting approval to return and re-enroll.

Once cleared to return from academic suspension, the Enrollment Services office will be notified and the student will be eligible to enroll. While on academic suspension, students are considered to be on a mandatory "leave of absence," and are governed by college and university policies concerning such leaves. See subsequent discussions of "Leave of Absence and Withdrawal from the College." Students returning from academic suspension do so on final academic probation.

Academic Drop

A student is dropped for academic reasons from the college and the university, and is not permitted to re-enroll when a student, already on final academic probation, continues to perform at levels below the minimum set by the college for good academic standing, and shows no indication of being able to reach an acceptable level of performance or maintain steady progress toward completing graduation requirements.

Undergraduate Economics Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

73-003 Transfer Credit

All Semesters

This number "holds" a place for an economics transfer credit courses so that these courses can be used in the academic audit system. Student receiving 73-003 credit have met the requirement of earning the equivalent of a "C" in their non-CMU economics course; however, have not earned the equivalent of a "B" which would provide credit for a CMU economics course equivalency.

73-060 Economics: BaseCamp

Fall: 3 units

This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-065 Nudging Behavior in Business and Public Policy

Spring: 3 units

This course applies the insights of Behavioral Economics to inform business and policy decisions. A nudge encourages desired behavior by framing the decision or environment such that various cognitive processes and heuristics are engaged in favor of the desired outcome. The use of this branch of social science has been used successfully by the UK and US governments by the Behavioural Insights Team and Social and Behavioral Sciences Team, respectively. Nudges have also been used effectively by the United Nations, via UNICEF, to address and change a variety of behaviors such as gender violence and sanitation practices. In 2016 the Supreme Committee for Delivery and Legacy founded the Qatar Behavioral Insights Unit (QBIU) and it was incorporated as a foundation under the Qatar Financial Center in 2019. This foundation is known as B4Development (B4D) and would be of interest and importance to CMUQ students. One of the partners of B4D is the Qatar Foundation.

73-102 Principles of Microeconomics

Fall and Spring: 9 units

The course is an introduction to microeconomic principles and how to think like an economist. Market and policy outcomes are largely a function of individual decisions. These questions typically take the form: how much and what combination of things should I buy? When do we want businesses to go bust? Should the government fund student tuition? It's my hope that you'll also start to think about everyday questions from an economic lens: why were bicycles so hard to find this past summer? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of government in the marketplace. Toward the end of the semester, we'll change a few underlying assumptions and address a variety of questions related to strategic interaction. Some of the topics we will begin to introduce include credible threats, commitment problems, and the strategic use of information. Not open to students who have received credit for 73-100. While there are no calculus pre-requisites for this course, students are encouraged to enroll in 73-102 after they've passed 21-111. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics

All Semesters: 9 units

A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour). Prerequisite: 73-102 Min. grade C

73-104 Principles of Microeconomics Accelerated

Intermittent: 9 units

This course is a rigorous introduction to microeconomic principles and how to think like an economist. The students are expected to have a successful, prior exposure to fundamental concepts and therefore, the course is at a faster pace than its sister course, 73102, and covers additional topics. The questions typically take the form: What is the optimal consumption pattern for me as an individual? What is the profit maximizing pattern of labor and capital goods for a firm? When do we want businesses to go bust? Should the government fund student tuition? How can firms hire the best match for them? Why kind of informational asymmetries exist in double-sided markets? It's my hope that the students start to think about everyday questions from an economic lens: Why were cars so hard to find during the pandemic? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of the third parties in the marketplace. Some later topics include credible threats, commitment problems, and the strategic use of information. Knowledge of basic calculus as covered in 21-111 would be helpful for the students. Only students with an AP Microeconomics Exam score of 4 or 5 and qualifying IB/Cambridge Economics exam scores are eligible to enroll in this course. Students without exam credit should enroll in 73-102 Principles of Microeconomics.

73-111 Internship I

All Semesters

By permission of the Undergraduate Economics Program.

73-112 Internship II

All Semesters: 3 units

The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-113 Internship III

All Semesters: 3 units

The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-155 Markets, Models, and Math

Spring: 9 units

The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws.

73-158 Markets, Models, and Math

Spring; 9 units

The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws. The course is also meant to introduce, in an intuitive way, the kinds of mathematical tools and reasoning that economists use, what the economic historian Philip Mirowski has called "the unreasonable efficacy of mathematics in economic analysis".

Prerequisites: 21-111 and 73-102 Min. grade C

73-199 Experiential Learning in Business and Economics

All Semesters; 3 units

Students will collaborate to create an economic newsletter called "Southwestern PA Economy in a Snapshot," a regional version of the well-known national version produced by the New York Fed (https://www.newyorkfed.org/medialibrary/media/research/snapshot/snapshot_january2021.pdf?la=en). The newsletter will lay the groundwork for a regular online publication produced by Carnegie Mellon Economics, a combination of data analysis/visualization and economic commentary. The ultimate goal is for the newsletter to be a to-go economics document for policy makers and business leaders in Pittsburgh and the surrounding region. Students will use a combination of data science skills, computer programming skills, and a basic knowledge of the relevant economic data. They will produce a professional, co-authored report that will serve as a valuable resume item for future career prospects. They will form small teams, each of which will create an Economic Commentary that uses the newsletter's data to provide analysis of a contemporary economic issue that is important for the Pittsburgh region. During the tenure of the course, students will also acquire new skills in computer programming, data analysis and economics. The course will "contribute to a broader body of knowledge" by obtaining, organizing and publicizing regional economic data where no such product currently exists. It will "identify and develop skills needed to approach and tackle a practical problem or issue." That is, students will take skills obtained in the single pre-req course (Principles of Macroeconomics) and combine them with skills that almost all 1st year students take in data analysis and produce a professional piece of economic analysis. They will see how their academic education can be applied in way that this useful to business people and policy makers.

Prerequisite: 73-102 Min. grade C

73-230 Intermediate Microeconomics

Fall and Spring; 9 units

This course builds on the Principles of Economics course. It focuses on the following topics: theory of the consumer, theory of the producer, perfectly competitive market equilibrium, imperfect competition, and market failures due to asymmetric information such as adverse selection and moral hazard. (Lecture, 3 hours; Recitation, 1 hour).

Prerequisites: (21-256 or 21-268 or 21-269 or 21-259) and (73-102 Min. grade C or 73-100 Min. grade C)

73-240 Intermediate Macroeconomics

Fall and Spring; 9 units

Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-256 and 73-100 Min. grade C) or (21-256 and 73-102 Min. grade C and 73-103 Min. grade C) or (21-259 and 73-100 Min. grade C) or (73-102 Min. grade C and 73-103 Min. grade C and 21-259)

73-255 Independent Study in Economics

Fall and Spring

The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case

Intermittent; 6 units

Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. <http://tinyurl.com/cmucoincourse> (<http://tinyurl.com/cmucoincourse/>) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science

All Semesters; 9 units

This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (70-207 or 36-247 or 36-225 or 36-220 or 36-219 or 36-218 or 36-217 or 36-207 or 36-202 or 36-201 or 36-200 or 21-325 or 15-259) and 73-102 Min. grade C

73-270 Professional Communication for Economists

Fall and Spring; 9 units

A writing course specifically designed for second-year and third-year Economics majors and additional majors. Students gain experience with technical writing techniques and skills needed for both their eventual professional careers. The course emphasizes both individual and group projects. (Seminar, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (76-108 or 76-107 or 76-106 or 76-102 or 76-101) and 73-102 Min. grade C and 73-103 Min. grade C

73-274 Econometrics I

Spring; 9 units

Data tools are important in guiding decisions and strategies for individuals, businesses, and policymakers. This course will prepare you for data-driven decision making, providing both theoretical backgrounds and empirical illustrations of the techniques that are necessary to cope with real-world (imperfect) data. Specifically, the course covers tools and methods for estimating economic relationships, testing economic theories, and evaluating business and government policy. This course builds on either of the two Statistical Reasoning courses (36-200/201) and the Economics and Data Science course (73-265), and it sets underpinnings for Econometrics II (73-275) for more advanced tools and insights for business and economics data analyses. Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.

Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and 73-265 Min. grade C and (73-240 Min. grade C or 73-230 Min. grade C)

73-315 Market Design

Intermittent: 9 units

In this course, we consider the design of various market mechanisms. We learn the typical causes of market failures and why we need to design new markets. For each topic, we start with a case study of a problem, develop a theory to address it, and consider its possible solutions. The class is roughly divided into three parts: matching, auctions, and further topics. In the first part, we study markets where there is no money and no prices (matching markets). Instead, we have people preferences over possible matching outcomes. Examples include placing doctors in residency positions, assigning students to schools, and assigning kidneys to transplant patients. We will learn algorithms that have desirable theoretical properties and are often used in practice. In the second part, we consider the problem of allocating of single or multiple goods (a house, a painting, or the rights to a natural resource such as oil or timber) using auctions. We discuss how different types of auctions work in theory and practice. We will look at the auctions used in financial markets to sell treasury bills, the auctions used by Google, Microsoft and Facebook to sell advertising, and the auctions used by governments to sell radio spectrum licenses. In the third part, we consider further important topics of market design. We will look into problems of high-frequency trading, digital markets, the allocation of refugees among European countries, and proposals to fix market for carbon pollution permits. An important goal of the course is to show how recent achievements of game theory and mechanism design lead to important practical applications and to inspire you to use these ideas in your life and workplace. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles

Intermittent: 9 units

For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and 73-240 Min. grade C

73-328 Health Economics

Fall: 12 units

This course will teach the student to use economic analysis to understand critical issues in health care and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.

Prerequisites: 21-120 and 73-102 Min. grade C

73-332 Political Economy

Spring: 9 units

The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations and #8212;in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.

Prerequisites: (73-230 Min. grade C or 73-160 Min. grade C) and (36-201 or 36-200)

73-337 Business of Blockchain

Intermittent: 9 units

Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different "tokenomics" models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 73-103 Min. grade C and 73-102 Min. grade C

73-338 Financial Crises and Risk

Fall: 9 units

This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and 73-102 Min. grade C and 73-240 Min. grade C

73-341 Managing through Incentives

Intermittent: 9 units

We live in an exciting age of information and knowledge when inspiring employees within a firm becomes increasing important. Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course, we learn how to reason about incentives between managers and employees, between managers and owners, and within a team of co-workers. We cover a broad range of topics including objective and subjective performance measurements, relative performance evaluations, relational contracts, and executive compensation. The course relies on business case discussions, rigorous theoretical material, and numerous class activities. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-259 or 21-268 or 21-269 or 21-256) and (36-217 or 36-225 or 36-218 or 36-219 or 36-220 or 36-200 or 36-207 or 70-207 or 36-202 or 36-201) and 73-230 Min. grade C

73-347 Game Theory Applications for Economics and Business

Fall: 9 units

An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

73-348 Behavioral Economics

Spring: 9 units

This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (36-200 or 36-225 or 36-207 or 36-217 or 70-207) and 21-120 and (73-102 Min. grade C or 73-100 Min. grade C)

73-352 Public Economics

Fall: 9 units

In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C

73-353 Financial Regulation in the Digital Age

Spring: 9 units

The financial crisis and the digitalization of the financial markets have focused attention on the role of regulation for our financial system and the broader economy in recent years. Among the settings that are especially important in the digital economy are electronic trading, big data, algorithms, robo investing, winner-take-all economics, securities offerings, property rights and cyber assets. The course will address the foundations of regulation ("why regulate?") from various perspectives within a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as disclosure, taxes and fees, antitrust prohibitions, privacy requirements, price regulation and guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? Why could it be beneficial to restrict permitted algorithms? Are our markets rigged? How suitable are antitrust remedies in the digital era? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? How can regulators enhance the predictability and credibility of their policies? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? To what extent did the Dodd-Frank Act ensure financial stability?(Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis

Intermittent: 9 units

The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individual's life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (73-102 Min. grade C or 73-100 Min. grade C) and (36-225 or 36-202 or 36-200 or 36-220 or 36-217 or 36-207 or 70-207)

73-365 Firms, Market Structures, and Strategy

Fall: 9 units

This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-269 or 21-259 or 21-256 or 21-268) and 73-230 Min. grade C

73-366 Designing the Digital Economy

Spring: 9 units

This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C and (36-208 or 36-220 or 36-226 or 70-208 or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 73-407 Min. grade C or 36-202)

73-369 Islamic Economics

Intermittent: 9 units

This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

73-374 Econometrics II

Fall: 9 units

The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses. Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and 73-230 Min. grade C and 73-274 Min. grade C

73-395 Independent Study in Economics

Fall and Spring

The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses. Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C)

73-408 Law and Economics

Intermittent: 9 units

This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such as regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: 21-120 and 73-102 Min. grade C

73-415 Data Driven Business and Public Policy Decision Making

Intermittent: 9 units

In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours; Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.

Prerequisites: (21-268 or 21-259 or 21-269 or 21-256) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets

Fall: 9 units

The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will also look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (36-207 or 36-200 or 36-202 or 70-207 or 15-259) and 73-102 Min. grade C and 73-103 Min. grade C

73-423 Forecasting for Economics and Business

Spring: 9 units

Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition. Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economics

Fall: 9 units

Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (73-102 Min. grade C or 73-100 Min. grade C) and (36-207 or 36-202 or 36-200 or 36-217 or 36-225 or 70-207 or 36-220)

73-469 Global Electronic Markets: Economics and the Internet

Fall: 9 units

The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.

Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and (73-230 Min. grade C or 73-160 Min. grade C)

73-476 American Economic History

Fall: 9 units

The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: 21-120 and (73-160 Min. grade C or 73-230 Min. grade C)

73-495 Advanced Independent Study in Economics

All Semesters

The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses.

Prerequisites: (21-259 or 21-268 or 21-269 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C)

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics> (<http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics/>)

73-497 Senior Project

Fall: 9 units

A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-256 or 21-259) and (73-407 Min. grade C or 73-374 Min. grade C or 73-274 Min. grade C or 73-265 Min. grade C or 36-226 or 36-303) and 73-230 Min. grade C and 73-240 Min. grade C

73-500 Tepper College Honors Thesis I

Fall and Spring

Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses. Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and (73-265 Min. grade C or 73-274 Min. grade C or 36-226 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-501 Tepper College Honors Thesis II

Fall and Spring

Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I. Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C and 73-500 Min. grade B and (73-265 Min. grade C or 73-374 Min. grade C)

Department of English

Andreea Ritivoi, Department Head
Location: Baker Hall 259
<https://www.cmu.edu/dietrich/english/>

The Department of English at Carnegie Mellon engages students in the important study of reading and writing as intellectual activities embedded in historical, cultural, professional, technological, and literary practices. Working with experts in their areas, students become effective writers and analysts of various kinds of texts in a range of media, from traditional print documents to film, multimedia, and on-line texts. Faculty use distinctive methods of studying texts, but all share a deep commitment to working in small and intense workshops and seminars to help students learn to become experts in analyzing existing texts, and in producing original and distinctive work of their own.

The English Department offers the following degree programs:

- B.A. in Creative Writing
- B.A. in Film & Visual Media
- B.A. in Literature & Culture
- B.A. in Professional Writing
- B.S. in Technical Writing

All five majors are structured to allow students to balance liberal and professional interests. Students in the **Creative Writing program** focus on analyzing and learning to produce poetic and narrative forms. Students in the **Film & Visual Media program** focus on cultural analysis, writing, production, and digital media. Students in the **Literature & Culture program** focus on the production and interpretation of print texts and other media in their social and cultural contexts. Students in the **Professional Writing program** focus on analyzing and producing non-fiction for a variety of professional contexts. Students in the **Technical Writing program** focus on integrating writing with technical expertise in a chosen area of concentration (*Technical Communication* or *Science & Medical Communication*). In addition to the five majors, we offer five departmental minors as well as two interdisciplinary minors, and we strongly encourage non-majors in the campus community to join us in English courses, beginning with offerings at the 200-level.

Students also get involved in a range of complementary activities, including a reading series of distinguished writers of poetry, fiction, and non-fiction; publishing, editing, and marketing through involvement with *The Oakland Review* and The Carnegie Mellon University Press; writing and editorial positions on the student newspaper, *The Tartan*, and other campus publications. We also offer a strong internship program that places student writers in media, non-profit, arts, corporate, and technical internships before they graduate. The end of every year culminates in a gala event to celebrate our students and their writing achievements in literary, academic, and professional writing. For this event, known as the Pauline Adamson Awards, we invite a well-known writer to do a public reading and then present and celebrate student writing awards in over a dozen categories, all judged anonymously by writing professionals from outside the university.

Majoring in English: The Five English Degree Options

The department of English offers students five degree options:

- The B.A. in Creative Writing
- The B.A. in Film & Visual Media
- The B.A. in Literature & Culture
- The B.A. in Professional Writing
- The B.S. in Technical Writing

Students who wish to broaden their experience with English courses may do so by taking more than the minimum requirements for each major or by combining two of the majors within the department for an additional major in English. Common combinations include, but are not limited to, a B.A. in Professional Writing with an additional major in Creative Writing; a B.A. in Creative Writing with an additional major in Literature & Culture; or a B.A. in Literature & Culture with an additional major in Professional Writing. Due to significant course overlap, students are not permitted to major in both Professional Writing and Technical Writing together. Consult the English Department and the section on "Completing an Additional Major in English" (p. 343) for further detail.

All of the English majors may be combined with majors and minors from other Carnegie Mellon departments and colleges. The English Department advisor can help you explore the available options so that you can choose a major or combination of programs that is appropriate for your interests and goals.

How the Curriculum is Structured

In addition to Dietrich College requirements, English majors complete 11 to 13 courses (99 to 117 units) specifically related to their chosen major within English and structured as indicated below. Please note that courses between majors/minors in the Department of English may not double count, with the exception of the Film & Visual Media major, due to its courses being pulled from multiple programs within English. A maximum of two courses may double count between Film & Visual Media and programs inside the Department of English. A maximum of two courses may double count for programs outside of the Department of English.

Core Requirements for the Specific Major (7 to 10 courses, 63 to 84 units)

Complete seven to ten courses.

The Core Requirements differ for each major and are designed explicitly to provide both breadth and depth within the specific major the student has chosen.

English Electives (3 to 4 courses, 27 to 36 units)

Complete three to four elective courses.

Elective Electives for the majors are designed to add breadth to each student's study within English and to provide experience with the range of approaches to reading and writing available within the department. Students in all English majors are encouraged to sample widely from the Department's offerings.

The B.A. in Creative Writing

Carnegie Mellon is one of only a few English departments in the country where undergraduates can major in Creative Writing (CW). In the CW major, students develop their talents in writing fiction, poetry, screenwriting, and creative nonfiction. While studying with faculty members who are writers, CW majors read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills, and develop a professional attitude toward their writing. The extracurricular writing activities and a variety of writing internships available on and off campus provide Creative Writing majors with valuable experiences for planning their future. After graduation, our Creative Writing majors go on to graduate writing programs and to careers in teaching, publishing, public relations, advertising, TV and film, freelance writing, and editing.

Students in the CW major are required to take two of the introductory genre writing courses: one in the spring of their first year, and one in the fall of their sophomore year. Choices include: 76-260 Introduction to Writing Fiction, 76-261 Introduction to Writing Creative Nonfiction, 76-265 Introduction to Writing Poetry, and 76-269 Introduction to Screenwriting. In order to proceed into the workshop courses, students must do well in these introductory courses (earn a grade of A or B). Creative Writing majors take four workshops in fiction, poetry, screenwriting, or nonfiction where the students' work is critiqued and evaluated by peers and the faculty. They also take courses in literature, including a Readings in Forms course where they spend a semester reading extensively in one genre.

Opportunities

During their senior year, students may write a Senior Project or Honors Thesis (if they qualify for Dietrich College honors) under the supervision of a faculty member.

Carnegie Mellon also offers CW majors various extracurricular opportunities for professional development, including internships both on- and off-campus. For example, they may work as interns with the Carnegie Mellon University Press, which is housed in the English Department. The Press publishes scholarly works, as well as books of poetry and short stories by both new and established American writers.

Students may help edit and submit their work for publication to The Oakland Review, a Carnegie Mellon University sponsored and student-run annual journal.

Students also have opportunities to read their works in a series of readings by student writers held in the Gladys Schmitt Creative Writing Center (also known as The Glad) and to hear nationally known authors as part of the Carnegie Mellon Visiting Writers series. Additionally, the English Department offers prizes for students each year in the writing of fiction, non-fiction, poetry and screenwriting. Student writers are celebrated during The Adamson Awards ceremony.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Creative Writing majors must complete 11 courses in the following areas:

Creative Writing Core (7 courses, 63 units)

Introductory Genre Writing Courses* (2 courses, 18 units):

| | | Units |
|--------|---|-------|
| 76-260 | Introduction to Writing Fiction | 9 |
| 76-261 | Introduction to Writing Creative Nonfiction | 9 |
| 76-265 | Introduction to Writing Poetry | 9 |
| 76-269 | Introduction to Screenwriting | 9 |

** A student must earn a grade of A or B in the introductory genre writing class in order to be eligible to enroll in a workshop of that same genre. A student who earns a grade of C in an introductory genre writing course may enroll in a related workshop only with the permission of the workshop professor. A student who earns a D or R in Survey of Forms may not take a workshop in that genre.

Reading in Forms (1 course, 9 units):

| | | Units |
|--------|--|-------|
| 76-362 | Reading in Forms: Nonfiction | 9 |
| 76-363 | Reading in Forms: Poetry & Prose (or Reading in Forms: Poetry) | 9 |
| 76-364 | Reading in Forms: Fiction | 9 |

Four Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit, except for Literary Journalism. Additionally, if a student has been accepted into the Dietrich College Senior Honors Program and is completing their thesis in the field of Creative Writing, they may use one semester of thesis credit (66-501 Dietrich College Senior Honors Thesis I or 66-502 Dietrich College Senior Honors Thesis II) to fulfill a workshop requirement.

| | | Units |
|--------|------------------------------|-------|
| 76-360 | Literary Journalism Workshop | 9 |
| 76-365 | Beginning Poetry Workshop | 9 |
| 76-460 | Beginning Fiction Workshop | 9 |
| 76-462 | Advanced Fiction Workshop | 9 |
| 76-465 | Advanced Poetry Workshop | 9 |
| 76-464 | Creative Nonfiction Workshop | 9 |
| 76-469 | Screenwriting Workshop | 9 |

English Electives (4 courses, 36 units)

Complete four additional courses from the English Department's offerings. Two of the four English Electives must be courses that are designated as fulfilling the literature requirement and focus on close reading of literary texts. Please consult the list of courses published each semester by the Department for current offerings. English Electives may include any course offered by the Department at the 200 level or above. Additionally, English Electives can include no more than one course at the 200 level. The remaining English Electives must be at the 300 or 400 level. In choosing Electives, students are encouraged to sample courses from across the Department.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two courses from other non-CMU programs/institutions toward the primary or additional major in Creative Writing or the BHA in Creative Writing, with the exception of one of the two required Introductory Genre Writing courses. Other transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (<https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html>) for more information.

Recommended Curriculum Pathway: B.A. in Creative Writing

This plan is the recommended pathway for completing the B.A. in Creative Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as the middle of their second semester. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Creative Writing via the Stellic Degree Audit Application (<https://www.cmu.edu/es/stellic/>).

| First-Year | | Second-Year | |
|--|---|--|--|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Communication Course | GEN ED: Foundations: Data Analysis Course | GEN ED: Foundations: Scientific Inquiry Course | GEN ED: Foundations: Intercultural & Global Inquiry Course |
| GEN ED: Disciplinary Perspectives: Humanities Course | GEN ED: Disciplinary Perspectives: Social Sciences Course | GEN ED: Foundations: Computational Thinking Course | GEN ED: Disciplinary Perspectives: Logic/Math Course |
| GEN ED: Grand Challenge Seminar Course | Introductory Genre Writing Course #1 | Introductory Genre Writing Course #2 | GEN ED: Equity & Justice Course |
| Free Elective | Free Elective | Reading in Forms Course | Creative Writing Workshop #1 |
| Free Elective | Free Elective | Free Elective | Free Elective |

| Third-Year | | Fourth-Year | |
|--|---|---|---|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Contextual Thinking Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | GEN ED: Disciplinary Perspectives: Additional Discipline Course (Business, Design, Engineering) | OPTIONAL GEN ED: Senior Capstone OR Free Elective |
| GEN ED: Disciplinary Perspectives: The Arts Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Creative Writing Literature Elective #2 | Creative Writing Workshop #4 |
| Creative Writing Literature Elective #1 | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Creative Writing English Elective #1 | Creative Writing English Elective #2 |
| Creative Writing Workshop #2 | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Creative Writing Workshop #3 | Free Elective |
| Free Elective | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Free Elective | Free Elective |

The B.A. in Film & Visual Media

The Film & Visual Media major trains students through a combination of coursework in:

- visual media,
- film history and analysis,
- screenwriting,
- and production of film and other visual media.

This major offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, as well as the development of a complex blend of creative, professional and technical competencies.

CMU's Department of English is an ideal home for the Film & Visual Media major due to the department's combination of creative writers, film

and media studies scholars, film makers, digital humanities and visual communication researchers.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Film & Visual Media majors must complete 12 courses in the following areas. **Note:** courses cannot double count between areas. For example, if you take 76-429 Introduction to Digital Humanities for the Digital Media area, you cannot also count that course for your Literature & Culture area.

Required introductory courses (2 courses, 18 units)

| Course | Units |
|-------------------------------------|-------|
| 76-239 Introduction to Film Studies | 9 |
| 76-259 Film History | 9 |

Production Courses (2 courses, 18-21 units)

| Required Course | Units |
|--|-------|
| 76-292 Introduction to Film Production * | 9 |

* Students who have completed 76-239 Introduction to Film Studies and/or 76-269 Introduction to Screenwriting will be given registration preference.

| Additional Production Course (options include but are not limited to:) | Units |
|--|-------|
| 54-191 Acting for Non-Majors | 9 |
| 60-110 Foundations: Time-Based Media | 10 |
| 60-125 IDeATe: Introduction to 3D Animation Pipeline | 12 |
| 60-141 Black and White Photography I | 10 |
| 60-218 IDeATe Portal: Real-Time Animation | 10 |
| 60-220 IDeATe: Technical Character Animation | 10 |
| 60-245 Portrait Photography | 10 |
| 60-333 IDeATe: Animation Rigging | 10 |
| 60-415 Advanced ETB: Animation Studio | 10 |
| 60-416 Advanced ETB: Documentary Storytelling | 10 |
| 76-374 Mediated Narrative | 9 |
| 76-481 Introduction to Multimedia Design | 12 |

Screenwriting Courses (2 courses, 18 units)

| Required Courses | Units |
|--------------------------------------|-------|
| 76-269 Introduction to Screenwriting | 9 |
| 76-469 Screenwriting Workshop | 9 |

Digital Media Courses (2 courses, 18-20 units)

| Options include but are not limited to: | Units |
|--|-------|
| 15-104 Introduction to Computing for Creative Practice | 10 |
| 60-125 IDeATe: Introduction to 3D Animation Pipeline | 12 |
| 60-142 Digital Photography I | 10 |
| 60-242 Digital Photography II | 10 |
| 62-150 IDeATe Portal: Introduction to Media Synthesis and Analysis | 10 |
| 76-314 Data Stories | 9 |
| 76-388 Coding for Humanists | 9 |
| 76-429 Introduction to Digital Humanities | 9 |

Literature & Cultural Studies Courses (2 courses, 18 units)

Course options include but are not limited to the following:

| Course | Units |
|--|-------|
| 76-203 Literature & Culture in the 18th Century | 9 |
| 76-207 Special Topics in Literature & Culture | 9 |
| 76-210 Banned Books | 9 |
| 76-221 Books You Should Have Read By Now | 9 |
| 76-232 Introduction to Black Literature | 9 |
| 76-245 Shakespeare: Tragedies & Histories | 9 |
| 76-247 Shakespeare: Comedies and Romances | 9 |
| 76-310 Advanced Studies in Film and Media | 9 |
| 76-313 Creative Visual Storytelling in Film Production | 9 |
| 76-314 Data Stories | 9 |

| | | |
|--------|--|---|
| 76-337 | Intersectional Feminism | 9 |
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-429 | Introduction to Digital Humanities | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 76-448 | Shakespeare on Film | 9 |

Topics in Film & Visual Media Studies Courses (2 courses, 18 units)

Course options include but are not limited to the following:

| Course | Units |
|---|-------|
| 76-312 Crime and Justice in American Film | 9 |
| 76-339 Topics in Film and Media (Can be taken more than once for credit, provided the course topic is new each time). | 9 |
| 76-353 Transnational Feminisms: Fiction and Film | 9 |
| 76-367 Fact Into Film: Translating History into Cinema | 9 |
| 76-448 Shakespeare on Film | 9 |
| 76-439 Seminar in Film and Media Studies | 9 |
| 79-225 West African History in Film | 9 |
| 79-306 Fact into Film: Translating History into Cinema | 9 |
| 79-308 Crime and Justice in American Film | 9 |
| 79-309 The Chinese Revolution Through Film (1949-2000) | 9 |
| 79-319 India Through Film | 6 |
| 79-326 Shall We Dance? Culture, Politics, and Movement in the 20th Century | 6 |
| 79-339 Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961) | 6 |
| 82-215 Arab Culture Through Dialogues, Film, and Literature | 9 |
| 82-278 Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-284 Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-296 World War I - the View from Paris & St. Petersburg | 6 |
| 82-355 Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film | 9 |

Recommended Courses

While not required, a few courses are recommended as a part of the curriculum. They include:

| | | |
|--------|------------------------------------|---|
| 76-310 | Advanced Studies in Film and Media | 9 |
| 76-323 | Text to Screen | 9 |
| 76-374 | Mediated Narrative | 9 |

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other programs outside of Carnegie Mellon University toward the primary or additional major in Film & Visual Media Studies, with the exception of 76-239 Introduction to Film Studies and 76-259 Film History Other transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (<https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html>) for more information.

Recommended Curriculum Pathway: B.A. in Film & Visual Media

This plan is the recommended pathway for completing the B.A. in Film & Visual Media in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as

the middle of their second semester. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Film & Visual Media via the Stellic Degree Audit Application (<https://www.cmu.edu/es/stellic/>).

| First-Year | | Second-Year | |
|--|--|--|--|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Communication Course | GEN ED: Foundations: Data Analysis Course | GEN ED: Foundations: Scientific Inquiry Course | GEN ED: Foundations: Intercultural & Global Inquiry Course |
| GEN ED: Disciplinary Perspectives: Social Humanities Course | GEN ED: Disciplinary Perspectives: Social Sciences Course | GEN ED: Foundations: Computational Thinking Course | GEN ED: Disciplinary Perspectives: Logic/Math Course |
| GEN ED: Grand Challenge Seminar Course | 76-310 Advanced Studies in Film and Media (recommended course, but not required) | 76-259 Film History | 76-469 Screenwriting Workshop |
| 76-239 Introduction to Film Studies (Also counts as GEN ED: Disciplinary Perspectives: The Arts) | Literature & Culture Course #1 | 76-269 Introduction to Screenwriting | Digital Media Course #1 |
| Free Elective | Free Elective | 76-292 Introduction to Film Production | Topics in Film Course #1 |

| Third-Year | | Fourth-Year | |
|--|--|---|---|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Contextual Thinking Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Topics in Film Course #2 | GEN ED: Disciplinary Perspectives: Additional (Business, Design, Engineering) | OPTIONAL GEN ED: Senior Capstone OR Free Elective |
| GEN ED: Equity and Justice Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. OR 76374 Mediated Narrative (recommended course, but not required) | Topics in Film Course #2 OR Free Elective | 76-374 Mediated Narrative (recommended course, but not required) OR Free Elective |
| Production Elective Course or 323 Text to Screen (which is a recommended course, but not required) | Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective | Free Elective | Free Elective |
| Literature & Culture Course #2 | Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective | Free Elective | Free Elective |
| Digital Media Course #2 | Open for course exploration, requirements for other majors/minors, study abroad, etc. OR Free Elective | Free Elective | Free Elective |

The B.A. in Literature & Culture

The Literature & Culture Major teaches students how to read, interpret and write persuasively about novels, poems, plays and other imaginative works across a variety of genres and media forms. Along with teaching students the analytical skills and methodological tools to interpret these works, this major teaches the importance of understanding imaginative works within their cultural and historical contexts. In addition, the major is designed to train students in strong professional and academic skills like critical thinking, inductive reasoning and persuasive argumentation that are applicable to other fields of study and a variety of career paths.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Literature & Culture majors must complete 13 courses in the following areas:

Requirements

13 courses, 117.0 units total

Required Introductory Courses (3 courses, 27 units)

| Course | Units |
|---|-------|
| 76-26X Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | 9 |
| 76-245 Shakespeare: Tragedies & Histories | 9 |

| | |
|--|---|
| or 76-247 Shakespeare: Comedies and Romances | |
| 76-275 Introduction to Critical Writing | 9 |

200-Level Literature & Culture Courses (2 courses, 18 units)

One course must cover the period of 1830 or before. **NOTE:** a single course cannot double count for both the Required Introductory Courses and the 200-Level Literature & Culture Courses. For example, you cannot count 76-245 Shakespeare: Tragedies & Histories as a *Required Introductory Course* as well as for the *200-Level Literature & Culture Course* for the 1830 or Before requirement.

Options include but are not limited to:

Courses 1830 or Before

| | |
|--|---|
| 76-203 Literature & Culture in the 18th Century | 9 |
| 76-230 Literature & Culture in the 19th Century | 9 |
| 76-233 Literature and Culture in the Renaissance | 9 |
| 76-245 Shakespeare: Tragedies & Histories (if not taken as one of the required introductory courses) | 9 |
| 76-247 Shakespeare: Comedies and Romances (if not taken as one of the required introductory courses) | 9 |

Additional 200-Level Courses

| Course | Units |
|--|-------|
| 76-207 Special Topics in Literature & Culture | 9 |
| 76-236 Major Fiction Then and Now | 9 |
| 76-278 Japanese Film and Literature: The Art of Storytelling | 9 |
| 76-282 Disability in Pop Culture | 9 |
| 76-210 Banned Books | 9 |
| 76-217 Literature & Culture of the 20th and 21st Century | 9 |
| 76-221 Books You Should Have Read By Now | 9 |
| 76-239 Introduction to Film Studies | 9 |
| 76-241 Introduction to Gender Studies | 9 |
| 76-242 American Woman Writers | 9 |
| 76-243 Introduction to Television | 9 |
| 76-245 Shakespeare: Tragedies & Histories | 9 |
| 76-244 Immigrant Fictions | 9 |
| 76-247 Shakespeare: Comedies and Romances | 9 |
| 76-259 Film History | 9 |
| 76-287 Sex & Texts | 9 |

300-Level Literature & Culture Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

| Course | Units |
|--|-------|
| 76-310 Advanced Studies in Film and Media | 9 |
| 76-312 Crime and Justice in American Film | 9 |
| 76-313 Creative Visual Storytelling in Film Production | 9 |
| 76-314 Data Stories | 9 |
| 76-317 Contemporary American Fiction | 9 |
| 76-326 Contemporary Global Literature | 9 |
| 76-329 Performing Race in Early Modernity | 9 |
| 76-337 Intersectional Feminism | 9 |
| 76-339 Topics in Film and Media | 9 |
| 76-341 Race & Gender in the Age of Jane Austen | 9 |
| 76-343 Rise of the American Novel | 9 |
| 76-349 Climate Fictions | 9 |
| 76-367 Fact Into Film: Translating History into Cinema | 9 |
| 76-392 Special Topics in Literature & Culture | 9 |

Theory Course (1 course, 9 units)

Course options include but are not limited to the following:

| Course | Units |
|---|-------|
| 76-337 Intersectional Feminism | 9 |
| 76-350 Critical Theories about Literature | 9 |
| 76-376 History of Critical Ideas | 9 |

Rhetoric Course (1 course, 9 units)

Course options include but are not limited to the following:

| Course | | Units |
|--------|---|-------|
| 76-325 | Intertextuality | 9 |
| 76-327 | Equity & Communication: Strategies for Institutional Change | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-373 | Argument | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-418 | Rhetoric and the Body | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-457 | Rhetorical Invention | 9 |
| 76-473 | Rhetoric & the Construction of Race | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-483 | Research Methods in Technical & Professional Communication | 9 |
| 76-492 | Rhetoric of Public Policy | 9 |

400-Level Capstone Seminar Course (1 course, 9 units)

Each semester, a 400-level course is designated as the Capstone Seminar. Literature & Culture majors are required to take this course in their final semester. Course options may include but are not limited to the following:

| Course | | Units |
|--------|---|-------|
| 76-408 | Culture and Globalization | 9 |
| 76-410 | The Long Eighteenth Century | 9 |
| 76-423 | Transnational Feminisms | 9 |
| 76-424 | Theories of Social Class | 9 |
| 76-429 | Introduction to Digital Humanities | 9 |
| 76-431 | Gender Play in Early Modern Drama | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 76-445 | Milton | 9 |
| 76-446 | Revenge Tragedy | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-449 | Race and Media | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 76-452 | Generations and Culture | 9 |
| 76-453 | Literature of Empire | 9 |
| 76-467 | Crime Fiction and Film | 9 |
| 76-468 | Space and Mobilities | 9 |
| 76-495 | Other People's Words: The History, Theory, and Practice of Interviews | 9 |

English Elective Courses (3 courses, 27 units)

Courses for the English Elective requirement can be fulfilled by choosing any of our 200- to 400-level courses. Students are encouraged to sample courses across our programs.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Literature & Culture or the BHA in Literature & Culture, with the exception of the Required Introductory Courses. Other transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (<https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html>) for more information.

Recommended Curriculum Pathway: B.A. in Literature & Culture

This plan is the recommended pathway for completing the B.A. in Literature & Culture in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as the middle of their second semester. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Literature & Culture via the Stellic Degree Audit Application (<https://www.cmu.edu/es/stellic/>).

| First-Year | | Second-Year | |
|--|--|---|--|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Communication Course | GEN ED: Foundations: Data Analysis Course | GEN ED: Foundations: Scientific Inquiry Course | GEN ED: Foundations: Intercultural & Global Inquiry Course |
| GEN ED: Disciplinary Perspectives: Humanities Course | GEN ED: Disciplinary Perspectives: Social Sciences Course | GEN ED: Foundations: Computational Thinking Course | GEN ED: Disciplinary Perspectives: Logic/Math Course |
| GEN ED: Grand Challenge Seminar Course | 76-245 Shakespeare: Tragedies & Histories (also fulfills the GEN ED: Foundations: Contextual Thinking requirement) if not fulfilled in Fall of First-Year, OR Free Elective) | GEN ED: Equity and Justice Course | 200-Level Literature & Culture Course #1 |
| 76-247 Shakespeare: Comedies and Romances (also fulfills the GEN ED: Foundations: Contextual Thinking requirement), OR Free Elective | Free Elective | 76-275 Introduction to Critical Writing | 200-Level Literature & Culture Course #2 |
| Free Elective | Free Elective | 76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | Free Elective |

| Third-Year | | Fourth-Year | |
|--|---|--|----------------------------|
| Fall | Spring | Fall | Spring |
| GEN ED: Disciplinary Perspectives: The Arts Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering) | 76-4xx Capstone Seminar |
| 300-Level Literature & Culture Course #1 | Open for course exploration, requirements for other majors/minors, study abroad, etc. | 300-Level Literature & Culture Course #2 | English Elective Course #2 |
| Theory Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | English Elective Course #1 | English Elective Course #3 |
| Rhetoric Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Free Elective | Free Elective |
| Free Elective | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Free Elective | Free Elective |

The B.A. in Professional Writing

Professional Writing (PW) combines a professional education with a strong foundation in rhetorical studies. The major prepares students for successful careers as writers and communications specialists in a range of fields, including but not limited to: editing and publishing, government, law, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing, and the arts.

The PW major includes 13 courses: 10 PW Core Requirements + 3 English Electives. The 10 Core Requirements include foundations courses in genre studies, editing, and argument, a professional seminar, plus a cluster of advanced rhetoric and specialized writing courses, all designed to closely integrate analysis and production. Through special topics courses — journalism, web design, advocacy writing, document design for print, science writing, public relations and corporate communications, writing for multimedia — students can pursue specializations while working with faculty who are both experts and practicing professionals in these fields. The 3-unit professional seminar, 76-300 Professional Seminar, which meets weekly during the fall term, provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields. PW majors also gain experience in working on team- and client-based projects and receive focused support to develop a portfolio of polished writing samples to use in applying for internships and employment. Through English Electives in Rhetoric, Creative Writing, and Literary and Cultural Studies, students gain additional practice in the careful reading, writing, and analysis of both literary and non-fictional texts and important insights into how texts function in their historical and contemporary contexts. As a capstone experience, senior PW majors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis in Rhetoric or Professional Writing. PW students can also apply for research grants through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace or pursue graduate study in fields as diverse as communications, law, business, and education. PW majors also have the opportunity to apply for the Department's accelerated MA in Professional Writing, the MAPW 4+1, which allows them to complete the degree in 2 semesters instead of the usual 3. Because the major in Professional Writing is deliberately structured as a flexible degree that allows a broad range of options, PW majors should consult closely with their English Department advisors on choosing both elective and required courses and in planning for internships and summer employment. Various opportunities for writers to gain professional experience and accumulate material for their writing portfolios are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus.

PW majors also have the option of taking writing internships for academic credit during their junior or senior year and are also strongly encouraged to seek professional internships throughout their undergraduate years and during their summers. Opportunities in public and media relations, newspaper and magazine writing, healthcare communication, publishing, technical writing, public service organizations, and writing for the web and new media illustrate both internship possibilities and the kinds of employment that Professional Writing majors have taken after graduation.

Curriculum

In addition to satisfying all of the Dietrich College degree requirements for B.A. candidates, Professional Writing majors must fulfill 13 requirements in the following areas:

Professional Writing Core (10 courses, 84 units)

Departmental Core Requirement (1 courses, 9 units):

| | | |
|-----------------------------------|---|---|
| Introductory Genre Writing Course | | |
| 76-260 | Introduction to Writing Fiction | 9 |
| 76-261 | Introduction to Writing Creative Nonfiction | 9 |
| 76-265 | Introduction to Writing Poetry | 9 |
| 76-269 | Introduction to Screenwriting | 9 |

Professional Writing Core Requirements (4 courses, 30 units):

| | | |
|--------|--|---|
| 76-271 | Introduction to Professional and Technical Writing | 9 |
| 76-300 | Professional Seminar | 3 |

| | | |
|--------|----------|---|
| 76-373 | Argument | 9 |
| 76-390 | Style | 9 |

Rhetoric/Language Studies Requirement (1 course, 9 units):

Complete one course from a set of varied offerings in Rhetoric/Language Studies as designated each term by the English Department. These courses focus explicitly on language and discourse as objects of study and emphasize the relationships of language, text structure, and meaning within specific contexts. Courses include but are not limited to the following:

| Course | | Units |
|--------|---|-------|
| 76-301 | Internship | Var. |
| 76-319 | Environmental Rhetoric | 9 |
| 76-325 | Intertextuality | 9 |
| 76-327 | Equity & Communication: Strategies for Institutional Change | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-359 | User Experience Methods for Documents | 9 |
| 76-360 | Literary Journalism Workshop | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-396 | Non-Profit Message Creation | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-476 | Rhetoric of Science | 9 |

Advanced Writing/Rhetoric Courses (4 courses, 36-42 units):

Complete four courses from a set of varied offerings in Advanced Writing/Rhetoric as designated each term by the English Department. Options include all courses that fulfill the Rhetoric requirement, plus additional courses in specialized areas of professional writing. Students should select courses in consultation with their English Department advisor or the Director of Professional Writing. Courses include but are not limited to the following:

| | | Units |
|--------|--|-------|
| 76-301 | Internship | Var. |
| 76-302 | Communication Support Tutoring Practicum | 6 |
| 76-314 | Data Stories | 9 |
| 76-319 | Environmental Rhetoric | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-354 | Watchdog Journalism | 9 |
| 76-359 | User Experience Methods for Documents | 9 |
| 76-360 | Literary Journalism Workshop | 9 |
| 76-372 | News Writing | 9 |
| 76-378 | Literacy: Educational Theory and Community Practice | 9 |
| 76-380 | Methods in Humanities Analytics | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-391 | Document & Information Design | 9 |
| 76-395 | Science Writing | 9 |
| 76-396 | Non-Profit Message Creation | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-418 | Rhetoric and the Body | 9 |
| 76-420 | The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-457 | Rhetorical Invention | 9 |
| 76-464 | Creative Nonfiction Workshop | 9 |
| 76-474 | Software Documentation | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-484 | Discourse Analysis | 9 |
| 76-485 | The New Public Sphere | 9 |
| 76-492 | Rhetoric of Public Policy | 9 |
| 76-487 | Information Architecture & Content Design (formerly titled Web Design) | 9 |
| 76-494 | Healthcare Communications | 9 |
| 76-496 | Research Methods in Rhetoric & Writing Studies (instructor permission required) | 9 |

English Electives (3 Courses, 27 Units)

Complete three courses from any of English Department's offerings (exceptions include 76-270, which is designed for non-majors). One may be at the 200-level or above; the remaining two must be at the 300- or 400-level. Two must be courses designated as Text/Context Electives, which focus on the relationship between texts and their cultural and historical contexts.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **Note:** courses being used for the Dietrich General Education requirements do not have a double-counting limit.

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Professional Writing or the BHA in Professional Writing, with the exception of the *Departmental Core Requirement* course and the *Professional Writing Core Requirement* courses. Other transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (<https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html>) for more information.

Recommended Curriculum Pathway: B.A. in Professional Writing

This plan is the recommended pathway for completing the B.A. in Professional Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as the middle of their second semester. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.A. in Professional Writing via the Stellic Degree Audit Application (<https://www.cmu.edu/es/stellic/>).

| First-Year | | Second-Year | |
|--|---|---|--|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Communication Course | GEN ED: Foundations: Data Analysis Course | GEN ED: Foundations: Scientific Inquiry Course | GEN ED: Foundations: Intercultural & Global Inquiry Course |
| GEN ED: Disciplinary Perspectives: Humanities Course | GEN ED: Disciplinary Perspectives: Social Sciences Course | GEN ED: Foundations: Computational Thinking Course | GEN ED: Disciplinary Perspectives: Logic/Math Course |
| GEN ED: Grand Challenge Seminar Course | 76-271 Introduction to Professional and Technical Writing | 76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | GEN ED: Equity and Justice Course |
| Free Elective | Free Elective | 76-300 Professional Seminar | 76-390 Style |
| Free Elective | Free Elective | Free Elective | Text/Context Course #1 |
| | | Free Elective | |

| Third-Year | | Fourth-Year | |
|--|---|--|--------------------------------------|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Contextual Thinking | Open for course exploration, requirements for other majors/minors, study abroad, etc. | GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering) | Optional GEN ED: Senior Capstone |
| GEN ED: Disciplinary Perspectives: The Arts Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Advanced Writing/ Rhetoric Course #2 | 76-373 Argument |
| Rhetoric/Language Studies Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Advanced Writing/ Rhetoric Course #3 | Advanced Writing/ Rhetoric Course #4 |
| English Elective | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Text/Context Course #2 | Free Elective |
| Advanced Writing/ Rhetoric Course #1 | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Free Elective | Free Elective |

The B.S. in Technical Writing

The B.S. in Technical Writing (TW) is one of the oldest undergraduate technical communication degrees in the country with a history that stretches back to 1958. The degree is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media.

Today's technical communicators have the strong backgrounds in technology, communication, and design needed to enter a broad range of information-based fields, and do work that both includes and goes well beyond writing documents for print distribution. The expanding range of options includes positions that involve organizing, managing, communicating, and facilitating the use of both technical and non-technical information in a range of fields and media.

Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems.

The B.S. in TW recognizes the important changes taking place in communication-based careers and includes two distinctive "tracks," one in Technical Communication (TC) and one in Scientific and Medical Communication (SMC). Both tracks begin with a common core of foundation courses in print and on-line communication as well as a shared set of prerequisites in math, statistics, and computer programming. The two tracks differ in the set of theory/specialization courses beyond the core, with each track including a specialized set appropriate to its focus.

In both tracks, TW students work on real projects for actual clients, learn group interaction and management skills, and develop a flexible repertoire of skills and strategies to keep up with advances in software and technology. Above all, they focus on developing structures and information strategies to solve a broad range of communication and information design problems.

TW students are able to draw on exceptional resources on and off campus to enhance their education. Most obvious are the course offerings of Carnegie Institute of Technology, the Mellon College of Science, and the School of Computer Science. Additional course offerings in business, organizational behavior, policy and management, psychology, history, and design are also encouraged. As a capstone experience, Seniors have the opportunity to complete a Senior Project or, upon invitation from the college, a Senior Honors Thesis. TW students can also apply for grants and fellowship through the Undergraduate Research Office to work on independent research projects with faculty.

While the major appeals to students with strong professional interests, both core and elective requirements develop the broad intellectual background one expects from a university education and prepare students to either enter the workplace upon graduation or pursue graduate study in fields as diverse as communications, business, instructional design, information design, education, and science and healthcare writing.

Various opportunities for writers to gain professional experience are available through campus publications, department-sponsored internships for academic credit, and writing-related employment on and off campus. TW students have the option of doing internships for academic credit

during their junior or senior year and are encouraged to pursue a series of internships throughout their 4 years and during their summers.

All TW students are required to enroll in the English Department's 3-unit course, Professional Seminar (76-300), which meets once a week during the fall term and provides majors with the opportunity to meet and network with practicing professionals in a range of communications fields.

The Technical Communication (TC) Track

The Technical Communication track (TC) prepares students for careers in the rapidly changing areas of software and digital media. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex communication systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences. The TW/TC major can be pursued as a primary major within Dietrich College or as an additional major for students in other Colleges with an interest in combining their specialized subject matter knowledge with strong writing and communications skills. Graduates of this track are likely to follow in the footsteps of previous TW students from Carnegie Mellon who are currently employed as web designers, information specialists, technical writers, and information consultants in a range of technology and communication-based organizations including Salesforce, IBM, Oracle, Microsoft, Apple, and HP Vertica.

The Scientific and Medical Communication (SMC) Track

The Scientific and Medical Communication track (SMC) is designed for students who seek careers that focus on communication and information design problems in health, science, and medicine. It should appeal to students with interests in the health care professions, science and public policy, patient education, scientific journalism and related fields. Like the TC track, the SMC track is designed to provide both the technical and the communication skills needed to analyze and solve complex communication problems. Students learn the fundamentals of visual, verbal, and on-line communication as well as the technical skills needed to design, communicate, and evaluate complex information systems and to manage the interdisciplinary teams needed to develop them. Students become fluent in both print-based and electronic media across a variety of information genres and learn to design information for a range of specialist and non-expert audiences. The TW/SMC major can be pursued as a primary major within Dietrich College or as a secondary major for students in other Colleges, such as MCS, with an interest in science or medicine.

Curriculum

All Technical Writing majors must satisfy the Dietrich College requirements for the B.S. degree, and a set of 3 to 4 prerequisite courses in calculus, statistics, and computer science. All prerequisites should be completed by the beginning of the fall semester, junior year. Prerequisites may double count toward Dietrich College Requirements or requirements for other majors or minors.

Mathematics Prerequisite (1 course, 10 units):

| Complete one of the following: | Units |
|---|-------|
| 21-111 Calculus I | 10 |
| 21-112 Calculus II | 10 |
| 21-120 Differential and Integral Calculus | 10 |
| 21-127 Concepts of Mathematics | 12 |

Statistics Prerequisite (1 course, 9 units):

| | |
|----------------------------|---|
| 36-200 Reasoning with Data | 9 |
|----------------------------|---|

Computer Science Prerequisites (1 - 2 courses*, 10 - 22 units):

| Students in the Technical Communication track must complete two required Computer Science courses: | Units |
|--|-------|
| 15-110 Principles of Computing | 10 |
| 15-112 Fundamentals of Programming and Computer Science | 12 |

| Students in the Scientific and Medical Communication track complete one required Computer Science course: | Units |
|---|-------|
| 15-110 Principles of Computing | 10 |

15-110 Principles of Computing is designed for students with little or no prior programming experience and is appropriate for students in both the

SMC and TC tracks. 15-112 Fundamentals of Programming and Computer Science prepares students in the TC track for all other advanced Computer Science courses.

Beyond these prerequisites, students in both TC and SMC tracks take a common set of 5 TW Core Requirements in writing, communication, and information design. To complement these foundations courses, TW students take a set of 3 Theory/Specialization courses specific to either TC or SMC. In addition, students in the SMC track take a series of 3 courses in the natural sciences or engineering relevant to their areas of interest, while TC students take 3 electives in management, technology, and social issues.

DEPARTMENTAL CORE REQUIREMENT (1 COURSE, 9 UNITS):

| Introductory Genre Writing Course | | |
|-----------------------------------|---|---|
| 76-260 | Introduction to Writing Fiction | 9 |
| 76-261 | Introduction to Writing Creative Nonfiction | 9 |
| 76-265 | Introduction to Writing Poetry | 9 |
| 76-269 | Introduction to Screenwriting | 9 |

TW Core Requirements (5 courses, 45 units):

| | | |
|--------|--|---|
| 76-271 | Introduction to Professional and Technical Writing | 9 |
| 76-300 | Professional Seminar | 3 |
| 76-390 | Style | 9 |
| 76-391 | Document & Information Design * | 9 |
| 76-487 | Information Architecture & Content Design (formerly titled Web Design) | 9 |

* prerequisite = 76-271 Introduction to Professional and Technical Writing
 **prerequisite = 76-271 Introduction to Professional and Technical Writing + 76-391 Document & Information Design

Theory/Specialization Courses (3 courses, 27 units):

Complete 3 courses to deepen your area of specialty and complement your chosen track (TC or SMC) in the major. One must be chosen from among courses designated as Recommended Options for TW majors. Theory/Specialization courses, including those marked as Recommended Options, are advertised by the English Department on a semester-by-semester basis. TW students should select courses in consultation with their academic advisor.

| Recommended courses include but are not limited to the following: | Units |
|---|-------|
| 76-319 Environmental Rhetoric | 9 |
| 76-359 User Experience Methods for Documents | 9 |
| 76-395 Science Writing | 9 |
| 76-425 Rhetoric, Science, and the Public Sphere | 9 |
| 76-474 Software Documentation | 9 |
| 76-476 Rhetoric of Science | 9 |
| 76-481 Introduction to Multimedia Design * | 12 |
| 76-491 Rhetorical Analysis | 9 |
| 76-494 Healthcare Communications | 9 |

| Additional Options include but are not limited to the following: | Units |
|---|-------|
| 76-301 Internship | Var. |
| 76-302 Communication Support Tutoring Practicum | 6 |
| 76-318 Communicating in the Global Marketplace | 9 |
| 76-319 Environmental Rhetoric | 9 |
| 76-325 Intertextuality | 9 |
| 76-351 Rhetorical Invention | 9 |
| 76-355 Leadership, Dialogue, and Change | 9 |
| 76-359 User Experience Methods for Documents | 9 |
| 76-360 Literary Journalism Workshop | 9 |
| 76-372 News Writing | 9 |
| 76-378 Literacy: Educational Theory and Community Practice | 9 |
| 76-389 Rhetorical Grammar | 9 |
| 76-395 Science Writing | 9 |
| 76-396 Non-Profit Message Creation | 9 |
| 76-419 Media in a Digital Age | 9 |
| 76-420 The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process | 9 |
| 76-425 Rhetoric, Science, and the Public Sphere | 9 |
| 76-474 Software Documentation | 9 |

| | | |
|--------|-----------------------------------|----|
| 76-475 | Law, Performance, and Identity | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-484 | Discourse Analysis | 9 |
| 39-605 | Engineering Design Projects | 12 |

Electives (3 courses, 27 units):

TW majors take 3 courses outside of English to deepen their area of specialty in their track. Typically, students in the Technical Communication (TC) track select courses that focus on management, technology, and social issues. Students in the Science and Medical Communication (SMC) track select courses in the natural sciences, engineering, statistics or (for example) healthcare-related courses in the Heinz College. (<https://www.heinz.cmu.edu/>) Students should work with their academic advisor and the Program Director to select courses that are meaningful for their track.

Double Counting

Students may double count up to two courses with other programs outside of the Department of English. **NOTE:** courses being used for the Dietrich General Education requirements do not have a double-counting limit. Also, the *Mathematics* and *Computer Science* prerequisite requirement courses for the Technical Writing major do not have a double-counting limit, nor do the Electives required for each specific track (TC track or SMC track).

Transfer Courses

Students may transfer up to two advisor-approved courses from other non-CMU programs/institutions toward the primary or additional major in Creative Writing or the BHA in Technical Writing, with the exception of the *Introductory Genre Writing Course* and *Technical Writing Core Requirement Courses*. Other transfer courses will be considered for general education requirements and free electives for graduation. Please see the Dietrich College Advanced Standing and Transfer Credit Policy (<https://www.cmu.edu/dietrich/advisory-center/scheduling-classes/ap-and-transfer-credit.html>) for more information.

Recommended Curriculum Pathway: B.S. in Technical Writing

This plan is the recommended pathway for completing the B.S. in Technical Writing in four years. While it is not required for students to follow this pathway precisely, it is highly recommended for students to do so, and we recommend students begin the major's courses as early as possible. Students in Dietrich College may declare their primary major as early as the middle of their second semester. Students who have not declared their major in the Department of English may still take courses with us.

Students may also view the four-year plan (also known as a Pathway) for the B.S. in Technical Writing via the Stellic Degree Audit Application (<https://www.cmu.edu/es/stellic/>).

| First-Year | | Second-Year | |
|--|---|---|---|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Communication Course | GEN ED: Foundations: Data Analysis Course | GEN ED: Foundations: Scientific Inquiry Course | GEN ED: Foundations: Intercultural & Global Inquiry Course |
| GEN ED: Disciplinary Perspectives: Humanities Course | GEN ED: Disciplinary Perspectives: Social Sciences Course | 15-112 Fundamentals of Programming and Computer Science (for TC Track students) OR Free Elective (for SMC Track students) | GEN ED: Equity and Justice Course |
| GEN ED: Grand Challenge Seminar Course | 15-110 Principles of Computing | 76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | 76-390 Style |
| Mathematics Prerequisite Course for TW Major | 76-271 Introduction to Professional and Technical Writing | 76-300 Professional Seminar | Technical Communication Elective #1 (TC Track students) OR Free Elective (SMC Track students) |
| Free Elective | Free Elective | Free Elective | Free Elective |

| Third-Year | | Fourth-Year | |
|---|---|---|---|
| Fall | Spring | Fall | Spring |
| GEN ED: Foundations: Contextual Thinking | Open for course exploration, requirements for other majors/minors, study abroad, etc. | GEN ED: Disciplinary Perspectives: Additional Course (Business, Design, Engineering) | Optional GEN ED: Senior Capstone |
| GEN ED: Disciplinary Perspectives: The Arts Course | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Theory and Specialization Course #1 (from Recommended List) | Theory and Specialization Course #3 |
| 76-391 Document & Information Design | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Theory and Specialization Course #2 | 76-487 Information Architecture & Content Design (formerly titled Web Design) |
| Technical Communication Elective #2 (TC Track students) OR Natural Science & Engineering Elective #1 (SMC Track students) | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Technical Communication Elective #3 (TC Track students) OR Natural Science & Engineering Elective #2 (SMC Track students) | Free Elective (TC Track students) OR Natural Science & Engineering Elective #3 (SMC Track students) |
| Free Elective | Open for course exploration, requirements for other majors/minors, study abroad, etc. | Free Elective | Free Elective |

*These courses must be taken in the sequence indicated. 76-271 is offered all semesters and therefore can be taken fall or spring of sophomore year. 76-271 is a prerequisite for 76-391, and 76-271 + 76-391 are the prerequisites for 76-487. 76-391 is typically only offered in the fall semesters, and 76-487 is typically only offered in spring semesters.

Completing an Additional Major in English

For Students with a Primary Major in the English Department

Students with a primary major in the English Department who have interests that include more than one of the department's majors have the option of completing an additional major within the department. Students may combine any of the departmental majors with one another, with the exception of Professional Writing and Technical Writing. Students may not combine these two majors because so many of the courses overlap.

Students with a primary major in the English Department and one or more additional majors in the English Department must fulfill the Core Requirements for each of those majors. The Survey of Forms requirement, common to all 5 majors, needs to be taken only once, with the exception of Creative Writing, which requires two Survey of Forms courses. For the English Department majors that require English Electives, students must complete the number of English Electives required by the major with the higher number of Electives. For example, a student with a primary major in Creative Writing and an additional major in Professional Writing would take 4 English Electives, as Creative Writing requires 4 English Electives, and Professional Writing requires only 3 English Electives.

Because students are only required to take a minimum of one Survey of Forms course, with the exception of Creative Writing, which requires two Survey of Forms courses, as well as the number of English Electives that is greater between the primary and additional major(s), students can generally add an additional major within the English Department by completing 6 to 9 additional courses.

An example:

A student who has fulfilled all 11 departmental requirements for the B.A. in Creative Writing can complete the additional major in Professional Writing by adding 9 courses: 4 courses of the PW Core (76-271 Introduction to Professional and Technical Writing, 76-300 Professional Seminar, 76-373 Argument, 76-390 Style), one Rhetoric/Language Studies course, and 4 Advanced Writing/Rhetoric courses.

Because sequencing of courses can become an issue when doing multiple majors, students are strongly advised to consult closely with the English Department academic advisor about the sequence of their courses. The English Department academic advisor can also provide students with documents that clearly outline the requirements for additional majors based on their primary majors within the Department.

For Students with a Primary Major Outside of the English Department

Students in other departments who wish to complete an additional major in the English Department should contact the English Department's academic advisor. Additional majors in the five English programs are required to complete all requirements for the chosen major. The English Department will allow a maximum of two courses from the additional major to double count with the primary major requirements. (The types of courses that apply to this policy are predetermined by the Department of English. See the English Academic Advisor for more details.) The only exceptions to this rule are the Technical Communication Electives for the *Technical Communication* concentration in the Technical Writing major and the Natural Science and Engineering Electives for the *Science & Medical Communication* concentration in the Technical Writing major. All of those electives may double count with programs outside of the English Department. In planning schedules for an additional major, it is critically important that students consult with academic advisors in both departments in which they are majoring to be sure that all requirements for graduation can be met.

Minor in English

The English Department also offers minors in **Creative Writing, Humanities Analytics, Literature & Culture, Professional Writing, and Technical Writing**. We also house two Dietrich College interdisciplinary minors in **Film and Media Studies** and **Gender Studies** (p. 564). All of these minors are available to all undergraduate students, including English majors.

Double Counting

Students who have a minor in English as well as a primary and/or an additional major in English may not double count any English courses with that minor. (Please see the separate double counting rules for the interdisciplinary minors in Film and Media Studies and Gender Studies.) Otherwise, up to two courses from the minor may double count with programs outside of the English Department. Courses that meet the various requirements are advertised on a semester-by-semester basis. Full descriptions are available each semester on the Department's Courses (<https://www.cmu.edu/dietrich/english/courses/>) web page.

Transfer Courses

Students may transfer in a maximum of one advisor-approved course from an institution outside of Carnegie Mellon University, **with the exception of the following courses**, to count toward a minor:

- Creative Writing: 76-26x Introductory Genre Writing Course
- Humanities Analytics: 76-275 Introduction to Critical Writing and 76-380 Methods in Humanities Analytics
- Film & Visual Media: 76-239 Introduction to Film Studies
- Literature & Culture: 76-275 Introduction to Critical Writing, 76-245 Shakespeare: Tragedies & Histories, and 76-247 Shakespeare: Comedies and Romances
- Professional Writing: *Required Intro Course* and the *Core Writing Courses*
- Technical Writing: *Required Intro Course* and the *Core Writing Courses*

Courses that meet the various requirements are advertised on a semester-by-semester basis. Full descriptions are available each semester on the Department's Courses (<https://www.cmu.edu/dietrich/english/courses/>) web page.

Creative Writing Minor

Complete 6 courses and a minimum of 54 units, which includes First-Year Writing.

| Course | Units |
|---|-------|
| First-Year Writing * | 9 |
| One Introductory Genre Writing Course † | 9 |
| 76-xxx Two 300/400 level Fiction, Poetry, and/or Screenwriting Workshop Classes | 18 |
| 76-3xx One Reading in Forms Course | 9 |
| 76-2xx One 200-level or above English Elective | 9 |

* Course options include 76-101, 76-102, [76-106 and 76-107], [76-106 and 76-108], or [76-107 and 76-108].

† A student must earn a grade of A or B in the Introductory Genre Writing course in order to be eligible to enroll in a workshop of that same genre. A student who earns a grade of C in an Introductory Genre Writing course

may enroll in a related workshop only with the permission of his/her/their workshop professor. A student who earns a D or R in an Introductory Genre Writing course may not take a workshop in that same genre.

† Course options include 76-260, 76-261, 76-265, and 76-269.

Humanities Analytics Minor

Tech CEOs and data scientists are increasingly calling for employees with more exposure to the humanities.

At the same time, the human experience that is traditionally at the core of a humanities education is being dramatically transformed by the emergence of big data, digital platforms, computational thinking, and digital connectivity.

Spurred by such developments, the minor in Humanities Analytics (HumAn) trains students in the processes involved in analyzing, digitizing, questioning, quantifying, and visualizing different types of humanities and cultural phenomena, such as printed books, fan fiction, manuscripts, historical records, art, music, and film.

The minor is open to students across multiple colleges and degree programs and enriches their education in distinct ways that complement their primary majors. For example, students with a primary major in a humanities or social science department will learn the foundational methods used in the computational analysis of text. Students with a primary major in a non-humanities field will use technology as a lens into cultural history and will develop skills for making humanities knowledge visible and appealing. The minor bridges divides not only between the "digital/technological" and the "humanistic," but also between the qualitative and quantitative, between theory and application, and between critiquing and making.

HumAn prepares students for careers in:

- Technology
- Data Science
- Data Journalism
- Cultural Commentary
- Natural Language Processing
- Professional Writing
- Publishing
- Museums
- Libraries
- Academia

Curriculum

Required Courses 6 courses, 54 units minimum

| Required Courses | Units |
|---|-------|
| 76-275 Introduction to Critical Writing | 9 |
| 76-380 Methods in Humanities Analytics | 9 |

| Two core courses from the following list: | Units |
|--|-------|
| 76-314 Data Stories | 9 |
| 76-388 Coding for Humanists | 9 |
| 76-425 Rhetoric, Science, and the Public Sphere | 9 |
| 76-429 Introduction to Digital Humanities | 9 |
| 88-275 Bubbles: Data Science for Human Minds | 9 |
| 88-300 Programming and Data Analysis for Social Scientists | 9 |

Electives 2 courses, 15-24 units

Choose two courses from the following categories. One course must come from List A, and one from List B. Additional courses not on List A or List B may also be approved as electives; please speak with the English Department academic advisor for more information.

List A

| Course Number & Title | Units |
|--|-------|
| 05-391 Designing Human Centered Software | 12 |
| 05-434/11-344 Machine Learning in Practice | 12 |
| 11-411 Natural Language Processing | 12 |
| 11-441/741 Machine Learning for Text and Graph-based Mining ¹ | 9 |

| | | |
|-----------|---|------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 16-223 | IDEATe Portal: Creative Kinetic Systems | 10 |
| 16-385 | Computer Vision | 12 |
| 17-340 | Green Computing | 9 |
| 17-450 | Crafting Software | 12 |
| 17-562 | Law of Computer Technology | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 36-204 | Discovering the Data Universe | 3 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-315 | Statistical Graphics and Visualization ² | 9 |
| 36-350 | Statistical Computing ² | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 48-095 | Spatial Concepts for Non-Architecture Majors | Var. |
| 48-120 | Digital Media I | 6 |
| 51-229 | Digital Photographic Imaging | 9 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 60/62-142 | Digital Photography I | 10 |
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis | 10 |

¹ Course is very mathematical and is therefore appropriate only to students with such a preparation.

² This course has prerequisites.

List B

| Course Number & Title | Units | |
|-----------------------|--|------|
| 76-210 | Banned Books | 9 |
| 76-245 | Shakespeare: Tragedies & Histories | 9 |
| 76-247 | Shakespeare: Comedies and Romances | 9 |
| 76-325 | Intertextuality | 9 |
| 76-373 | Argument | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-491 | Rhetorical Analysis | 9 |
| 79-200 | Introduction to Historical Research & Writing | 9 |
| 79-234 | Technology and Society | 9 |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-480 | Translation Technologies | 9 |

Literature & Culture Minor

Complete 6 courses and a minimum of 54 units, including First-Year Writing as a prerequisite.

Curriculum

| | | |
|--------------------------|--|---|
| Required Courses | 6 courses, 54 units | |
| Two Introductory Courses | Units | |
| 76-275 | Introduction to Critical Writing | 9 |
| 76-26x | Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | 9 |

18

200-Level Literature & Culture Courses (2 courses, 18 units)

One course must cover the period of 1830 or before. For example, Course options include but are not limited to the following:

| Courses for 1830 or Before | | Units |
|---|--|-------|
| 76-203 | Literature & Culture in the 18th Century | 9 |
| 76-230 | Literature & Culture in the 19th Century | 9 |
| 76-233 | Literature and Culture in the Renaissance | 9 |
| 76-245 | Shakespeare: Tragedies & Histories | 9 |
| 76-247 | Shakespeare: Comedies and Romances | 9 |
| Courses include but are not limited to: | | Units |
| 76-203 | Literature & Culture in the 18th Century | 9 |
| 76-207 | Special Topics in Literature & Culture | 9 |
| 76-210 | Banned Books | 9 |
| 76-217 | Literature & Culture of the 20th and 21st Century | 9 |
| 76-221 | Books You Should Have Read By Now | 9 |
| 76-230 | Literature & Culture in the 19th Century | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-233 | Literature and Culture in the Renaissance | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-290 | Literature & Culture in the 20th Century | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-245 | Shakespeare: Tragedies & Histories (if not taken for pre-1830 requirement) | 9 |
| 76-247 | Shakespeare: Comedies and Romances (if not taken for pre-1830 requirement) | 9 |
| 76-259 | Film History | 9 |
| 76-287 | Sex & Texts | 9 |

300- or 400-Level Literature & Culture or Theory Courses (2 Courses, 18 units)

Course options include but are not limited to the following:

| Courses include but are not limited to: | | Units |
|---|--|-------|
| 76-310 | Advanced Studies in Film and Media | 9 |
| 76-313 | Creative Visual Storytelling in Film Production | 9 |
| 76-314 | Data Stories | 9 |
| 76-315 | 19th Century American Literature | 9 |
| 76-317 | Contemporary American Fiction | 9 |
| 76-326 | Contemporary Global Literature | 9 |
| 76-329 | Performing Race in Early Modernity | 9 |
| 76-333 | Race and Controversy in the Arts | 9 |
| 76-337 | Intersectional Feminism | 9 |
| 76-339 | Topics in Film and Media | 9 |
| 76-343 | Rise of the American Novel | 9 |
| 76-350 | Critical Theories about Literature | 9 |
| 76-352 | Music, Technology, and Culture | 9 |
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-367 | Fact Into Film: Translating History into Cinema | 9 |
| 76-429 | Introduction to Digital Humanities | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 76-445 | Milton | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-449 | Race and Media | 9 |
| 76-452 | Generations and Culture | 9 |
| 76-453 | Literature of Empire | 9 |
| 76-454 | Rise of the Blockbuster | 9 |
| 76-467 | Crime Fiction and Film | 9 |

Professional Writing Minor

Complete 6 courses and a minimum of 54 units.

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| Required Intro Course | Units | |
| 76-270 | Writing for the Professions | 9 |
| or 76-271 | Introduction to Professional and Technical Writing | |

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| Two 200- or 300-Level Core Writing Courses | Units |
| 76-26x Introductory Genre Writing Course (Fiction, Creative Nonfiction, Poetry, or Screenwriting) | 9 |
| 76-373 Argument | 9 |
| 76-389 Rhetorical Grammar | 9 |
| 76-390 Style | 9 |
| Two 300- or 400-Level Writing Courses (18 units minimum) | Units |
| 76-306 Editing and Publishing (requires instructor permission) | Var. |
| 76-308 Literary Journal Publishing | Var. |
| 76-314 Data Stories | 9 |
| 76-318 Communicating in the Global Marketplace | 9 |
| 76-325 Intertextuality | 9 |
| 76-351 Rhetorical Invention | 9 |
| 76-354 Watchdog Journalism | 9 |
| 76-360 Literary Journalism Workshop | 9 |
| 76-372 News Writing | 9 |
| 76-384 Race, Nation, and the Enemy | 9 |
| 76-388 Coding for Humanists | 9 |
| 76-391 Document & Information Design | 9 |
| 76-395 Science Writing | 9 |
| 76-396 Non-Profit Message Creation | 9 |
| 76-397 Instructional Text Design | 9 |
| 76-415 Mediated Power and Propaganda | 9 |
| 76-418 Rhetoric and the Body | 9 |
| 76-420 The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process | 9 |
| 76-425 Rhetoric, Science, and the Public Sphere | 9 |
| 76-457 Rhetorical Invention | 9 |
| 76-474 Software Documentation | 9 |
| 76-475 Law, Performance, and Identity | 9 |
| 76-476 Rhetoric of Science | 9 |
| 76-481 Introduction to Multimedia Design | 12 |
| 76-484 Discourse Analysis | 9 |
| 76-492 Rhetoric of Public Policy | 9 |
| 76-487 Information Architecture & Content Design (formerly titled Web Design) | 9 |
| 76-494 Healthcare Communications | 9 |
| 76-496 Research Methods in Rhetoric & Writing Studies (requires instructor permission) | 9 |

One 200-Level or Above English Elective
Students may choose from the Department's listings. Please contact the academic advisor for more information.

Technical Writing Minor

Complete 6 courses and a minimum of 54 units.

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| Required Intro Course | Units |
| 76-270 Writing for the Professions or 76-271 Introduction to Professional and Technical Writing | 9 |
| Two 200- or 300-Level Core Writing Courses | Units |
| 76-373 Argument | 9 |
| 76-389 Rhetorical Grammar | 9 |
| 76-390 Style | 9 |
| 76-391 Document & Information Design | 9 |
| Two 300- or 400-Level Theory/Specialization Courses (18 units minimum) | Units |
| 76-301 Internship (requires department approval) | Var. |
| 76-302 Communication Support Tutoring Practicum | Var. |
| 76-314 Data Stories | 9 |
| 76-318 Communicating in the Global Marketplace | 9 |
| 76-380 Methods in Humanities Analytics | 9 |
| 76-395 Science Writing | 9 |
| 76-397 Instructional Text Design | 9 |
| 76-474 Software Documentation | 9 |
| 76-476 Rhetoric of Science | 9 |

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| 76-481 Introduction to Multimedia Design | 12 |
| 76-483 Research Methods in Technical & Professional Communication | 9 |
| 76-487 Information Architecture & Content Design (formerly titled Web Design) | 9 |
| 76-496 Research Methods in Rhetoric & Writing Studies (requires instructor approval) | 9 |
| Additional 300- or 400-Level Theory/Specialization Course | Units |
| In addition to any of the courses above that have not already been taken, courses include but are not limited to: | |
| 76-306 Editing and Publishing (requires instructor approval) | Var. |
| 76-318 Communicating in the Global Marketplace | 9 |
| 76-325 Intertextuality | 9 |
| 76-354 Watchdog Journalism | 9 |
| 76-360 Literary Journalism Workshop | 9 |
| 76-372 News Writing | 9 |
| 76-384 Race, Nation, and the Enemy | 9 |
| 76-389 Rhetorical Grammar | 9 |
| 76-415 Mediated Power and Propaganda | 9 |
| 76-418 Rhetoric and the Body | 9 |
| 76-457 Rhetorical Invention | 9 |
| 76-464 Creative Nonfiction Workshop | 9 |
| 76-475 Law, Performance, and Identity | 9 |
| 76-492 Rhetoric of Public Policy | 9 |
| 76-494 Healthcare Communications | 9 |

Senior Honors Thesis

Seniors in all five majors in the English Department who meet the necessary requirements are invited by the College of Humanities and Social Sciences (Dietrich College) to propose and complete a Senior Honors Thesis during their final year of study. The thesis may focus on research and/or original production in any of the areas offered as a major within the Department. To qualify for the Dietrich College Honors Program, students must have a cumulative Quality Point Average (QPA) of at least 3.50 in their major and 3.25 overall at the end of their junior year and be invited by Dietrich College to participate. Students then choose a thesis advisor within the Department and propose and get approval from Dietrich College for a Senior Honors Thesis. The Honors Thesis is completed over the two semesters of the senior year (9 units each semester) under the direction of the chosen advisor. By successfully completing the thesis, students earn 18 units of credit and qualify for graduation with "College Honors."

Creative Writing majors participating in the Senior Honors Thesis program may petition to have one semester of their thesis work count as one of their Workshop course requirements. Students interested in this option should contact the Director of Undergraduate Studies.

Internship Program

Qualified students in all five of the Department's degree programs have the option of doing a professional internship for academic credit during their junior or senior years. These opportunities help students explore possible program-related careers as well as gain workplace experience. Each internship is arranged, approved, and overseen by the Department's Internship Director. Particular attention is given to matching students to internship sites of specific interest to them. Students have interned in a wide variety of communications-related positions including placements at local radio, television, and print publications; museums, theaters, and cultural organizations; non-profit and public service organizations; public relations, advertising, and marketing firms; software and technology companies; new media organizations; and hospitals and healthcare communication organizations.

To be eligible for an internship, students must have a Quality Point Average (QPA) of 3.0 or better and credit for at least one writing course (including Survey of Forms) beyond First-Year Writing (e.g. 76-101 Interpretation and Argument). Internships generally carry 3-12 units of credit. A 9-unit internship is the standard and requires a minimum of 120-140 hours (8-10 hours per week over a 15-week term) of work at the internship site during the term. In addition, interns complete a reflective journal and a series of short research and writing assignments relevant to the specific internship. Students doing an internship for credit must be registered for the internship during the term (including summer) when they are working at the internship site. Majors in the Department may count one 9- to 12-unit internship for one of their major requirements, generally an English elective, but

sometimes as an Advanced Writing requirement for Professional Writing majors.

Students may pursue additional internships for credit, which may count toward their overall units for graduation. For details, see the Dietrich College's Academic Standards, Regulations, and Protocols in the current Undergraduate Catalog.

The Accelerated MA in Professional Writing: MAPW 4+1

The Master of Arts in Professional Writing (MAPW) 4+1 is an accelerated masters program under which Carnegie Mellon students (usually majors or minors in the English department or BHA or BHS students with relevant coursework) can qualify to complete the M.A. in Professional Writing in 2 semesters and a required full-time internship instead of the usual 3 semesters and a summer internship. Most 4+1 students complete their internship requirement during the summer after their graduation.

Students apply for admissions during their senior year (the GRE is not required) and, following admission and evaluation of their transcripts, may receive credit for up to four courses, or one full semester of work, toward their M.A. requirements. The degree provides the advantages of an M.A. degree in an accelerated time frame, features intensive work in writing and visual design for both print and new media, and prepares students for a range of communications careers.

The coursework and career options most commonly pursued by students in the degree include:

- Technical Writing
- Science and Healthcare Writing
- UX Writing/Content Design
- Information Architecture
- Public & Media Relations / Corporate Communications
- Nonprofit & Policy Communication
- Editing and Publishing

Students interested in applying to the 4+1 program should consult the Director of the MAPW program early in their junior year for further details and advice on shaping undergraduate coursework to qualify for this option.

Faculty

MARIAN AGUIAR, Associate Professor of English – Ph.D., University of Massachusetts;

JANE BERNSTEIN, Professor of English – M.F.A., Columbia University;

DAVID BROWN, Associate Teaching Professor of English, Associate Director of First-Year Writing for Research and Assessment – Ph.D., Lancaster University;

GERALD P. COSTANZO, Professor of English – M.A., M.A.T., The Johns Hopkins University;

DOUG COULSON, Associate Professor of English – Ph.D., The University of Texas at Austin;

JAMES DANIELS, Professor Emeritus of Creative Writing – M.F.A., Bowling Green State University;

SHARON DILWORTH, Associate Professor of English – M.F.A., University of Michigan;

JASON ENGLAND, Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

LINDA FLOWER, Professor Emerita of English – Ph.D., Rutgers University;

KEVIN GONZÁLEZ, Assistant Professor of English – M.F.A., Iowa Writers' Workshop;

SUSAN HAGAN, Assistant Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

PAUL HOPPER, Paul Mellon Distinguished Professor Emeritus of the Humanities, Rhetoric and Linguistics – Ph.D., University of Texas;

SARAH HAE-IN IDZIK, Assistant Professor of English – Ph.D., Northwestern University;

SUGURU ISHIZAKI, Professor of English, Director of Undergraduate Professional & Technical Writing Programs and Graduate Professional Writing Program (MAPW) – Ph.D., Massachusetts Institute of Technology;

BARBARA JOHNSTONE, Professor Emerita of English and Linguistics – Ph.D., University of Michigan;

DAVID S. KAUFER, Mellon Distinguished Professor Emeritus of English – Ph.D., University of Wisconsin;

ALAN KENNEDY, Professor Emeritus of English – Ph.D., University of Edinburgh;

JON KLANCHER, Professor Emeritus of English – Ph.D., University of California at Los Angeles;

PEGGY KNAPP, Professor Emerita of English – Ph.D., University of Pittsburgh;

STEPHANIE LARSON, Assistant Professor of English – Ph.D., University of Wisconsin-Madison;

ATESEDE MAKONNEN, Assistant Professor of English – Ph.D., The Johns Hopkins University;

JANE MCCAFFERTY, Professor of English, Director of Creative Writing Program – M.F.A., University of Pittsburgh;

TOM MITCHELL, Assistant Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

CHRISTINE NEUWIRTH, Professor Emerita of English and Human Computer Interaction – Ph.D., Carnegie Mellon University;

KATHY M. NEWMAN, Associate Professor of English and Director of Graduate Studies – Ph.D., Yale University;

JOHN J. ODDO, Associate Professor of English – Ph.D., Kent State University;

SILVIA PESSOA, Associate Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Carnegie Mellon University;

CAMILLE RANKINE, Assistant Professor of English – M.F.A., Columbia University;

DUDLEY REYNOLDS, Teaching Professor, Liberal & Social Sciences, Carnegie Mellon University-Qatar – Ph.D., Indiana University, Bloomington;

ANDREEA DECIU RITIVOI, William S. Dietrich Professor of English, Department Head – Ph.D., University of Minnesota;

KAREN SCHNAKENBERG, Teaching Professor Emerita of English – Ph.D., Carnegie Mellon University;

LAUREN SHAPIRO, Associate Professor of English – M.F.A., Iowa Writers' Workshop;

DAVID R. SHUMWAY, Professor of English, Director of Literary and Cultural Studies Program – Ph.D., Indiana University;

KRISTINA STRAUB, Professor Emerita of English – Ph.D., Emory University;

CHRISTOPHER WARREN, Professor of English and Associate Department Head with a Courtesy Appointment in History – D. Phil., University of Oxford;

MARIAM WASSIF, Assistant Professor of English – Ph.D., Cornell University;

DANIELLE WETZEL, Teaching Professor; Director of Writing & Communication Program – Ph.D., Carnegie Mellon University;

JEFFREY WILLIAMS, Professor of English – Ph.D., Stony Brook University;

STEPHEN WITTEK, Associate Professor of English – Ph.D., McGill University;

JOANNA WOLFE, Teaching Professor of English – Ph.D., The University of Texas at Austin;

JAMES WYNN, Associate Professor of English, Director of Rhetoric Program – Ph.D., University of Maryland;

Special Faculty

KEELY AUSTIN

MARIO CASTAGNARO, Special Faculty

MEG FELLER

EMMA FRIES

ANDREW GORDON

MEGAN HEISE

ALAN HOUSER

CHRISTOPHER MAGGIO

KORRYN MOZISEK

JULIE PAL-AGRAWAL

JULIA SALEHZADEH

BRIAN STASZEL

ISABELLE STROLLO

STEVE TWEDT

RALPH VITUCCIO, Assistant Teaching Professor in the Entertainment
Technology Center

Visiting Faculty

KOEL BANERJEE, Visiting Postdoctoral Fellow of English - Ph.D., University of
Minnesota;

Lecturer

JANINE CARLOCK, Visiting Lecturer, Writing & Communication

BARBARA GEORGE

JEFFREY HINKELMAN, Senior Lecturer and Director of the Film & Visual Media
Program

ALAN KOHLER, Lecturer, Writing & Communication

PETER ZARAGOZA MAYSHLE, Lecturer, Writing & Communication

COURTNEY NOVOSAT, Lecturer, Writing & Communication

JEREMY ROSSELOT-MERRITT, Lecturer, Writing & Communication

REBECCA WIGGINTON, Lecturer, Writing & Communication

HEIDI WRIGHT, Senior Lecturer, Writing & Communication - Course Lead,
ENG 76-100,

JUNGWAN YOON, Lecturer, Writing & Communication

Department of English Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

76-050 Study Abroad

All Semesters

No course description provided.

76-100 Reading and Writing in an Academic Context

Fall and Spring: 9 units

76-100 is an academic reading and writing course for multilingual students, especially those who are not native speakers of English or who consider English to be their weaker language. The course emphasizes reading comprehension strategies for reading a variety of text types in English (e.g., journalism, textbook selections, popular press arguments, and academic journal articles). Throughout the semester, students use these sources to write summaries and short position papers. The course introduces students to readers' expectations for North American rhetorical style at the sentence, paragraph, and whole text or genre levels. Within the course we discuss explicit genre and linguistic norms for writing in academic English so that writers can connect with their readers. Students who take this course qualify through an online placement test that is administered through the university prior to the fall semester. (All sections are offered MWF). Each 76-100 course is structured by the reading and writing objectives of the course as well as a vocabulary for writing in English, but some courses present different themes (or content) in their readings.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-101 Interpretation and Argument

All Semesters: 9 units

Interpretation and Argument is a foundational, inquiry-driven writing course that introduces students to a variety of strategies for making compositional decisions in writing and communication. Within the course, students learn genre-based skills applicable to a variety of different fields. Students use a comparative genre analysis method to learn how to use models to take on new writing tasks, including an academic research proposal and a research article that contributes to an ongoing academic conversation. Faculty who teach 76-101 typically select texts, ranging from scholarly texts, journalism, and film, about an issue so that students can identify interesting questions for their own research projects. Students should expect explicit, research-based instruction, practice, and reflection to build knowledge in controlling their writing processes and writing clear, well-supported, reader-oriented arguments. Because the course emphasizes the real stakes of communicating with readers and listeners, students share with their peers both low and high stakes written work within an interactive and collaborative classroom environment. Due to the limits of our schedule, we are unable to meet each student's individual preferences for course topics, but we do offer a wide variety from which to choose. Section descriptions are posted at the course URL below.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-102 Advanced First Year Writing: Special Topics

Fall and Spring: 9 units

76-102, Advanced First-Year Writing courses are designed for students who have demonstrated an understanding of academic writing that most incoming freshmen have not. Because of the students' level of preparedness, the First-Year Writing Program provides intensive, advanced courses for students to work closely with senior faculty within the English department. Advanced courses assume that students have established strong reading and synthesizing skills, as well as a demonstrated interest in writing and communication, prior to entering Carnegie Mellon. The course topics shift each semester. Students enroll through special invitation. Class size for 76102 is capped at 19 and there are no prerequisites for the course. Advisors will be notified if their students qualify for the advanced writing courses.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-106 Writing about Literature, Art and Culture

Fall and Spring: 4.5 units

This mini course (one of two minis students can choose to fulfill their FYW requirement) uses artistic, literary, and cultural texts (e.g., poetry, short story, lyrics, video clips) to introduce students to a variety of academic reading and writing practices that enable students to engage with texts and write about them with complexity and nuance. Within the course, we will discuss texts and evidence from multiple perspectives. We will examine how literary and cultural scholars write about texts (defined broadly), how they make claims, provide reasoning, and use textual support to argue for particular ways of seeing cultural objects. Throughout the semester, students will draw upon prior strategies and develop new ones for close reading and for critical analysis in order to produce their own thesis-driven arguments about why texts matter. We will consider and write about the extent to which these reading strategies are relevant for other kinds of reading and analysis by comparing texts from a variety of different disciplinary contexts.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-107 Writing about Data

Fall and Spring: 4.5 units

Our lives are increasingly shaped by writing that involves numbers: newspapers routinely report the latest medical fads; politicians support their political agendas with both dubious and credible statistics; parents use data to decide where to buy a house and where to send their kids to school. This course (one of two minis students can choose to fulfill their FYW requirement) focuses upon interpreting and making arguments using mainly numerical data but also qualitative data. We will look at research in a range of disciplines including psychology, education, medicine, engineering, and the sciences and note how writers select and analyze the data they collect. We will also examine what happens to this research when it is picked up by the popular media. Students will also practice collecting and analyzing their own data and reporting it to suit the needs of various stakeholders. There are two primary audiences for this section. Students in data-driven majors will find the section useful preparation for communicating in their disciplines. Students in other fields will learn how to critique and respond to the many ways that numbers shape our lives. This section presumes a basic ability to calculate averages, percentages, and ratios, but no advanced mathematical or statistical preparation. Instead, this section provides a fascinating look at how numbers and words intersect to create persuasive arguments in academic, professional, and popular contexts. Students will compare and analyze texts that make arguments with data, practice rhetorical strategies for synthesizing and representing data so that by the end of the class, students will apply these strategies to write an original data-driven research proposal.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-108 Writing about Public Problems

Fall and Spring: 4.5 units

If all problems required a simple fix, we could don our Avenger costumes, pick up Thors hammer, and right the worlds wrongs. But most problems aren't so simple. Most of the problems we encounter require careful investigation and research so that we might propose solutions that connect with others to make change. In this 76101 class (one of two mini students can choose to fulfill their FYW requirement), we will learn how public problems are defined and argued across a range of texts, including proposals, op-ed genres, and white papers. By analyzing a range of proposal texts, we will identify the different kinds of legwork necessary to write a successful proposal, arguably one of the most challenging aspects of writing a persuasive recommendation for change. We will examine how writers unpack problems rhetorically and use evidence to argue solutions for different stakeholders who may not share common values. We will learn strategies for evaluating and synthesizing data from existing research to use in a proposal argument. By the end of the course, students will write their own proposal that recommends a solution and a feasible plan for solving a real problem.

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-203 Literature & Culture in the 18th Century

Fall: 9 units

Topics vary by semester. Fall 2022 This section will examine race, gender, and their intersections as points of entry into the major literary and cultural movements of the long eighteenth century, which continue to shape our present. From about 1660 to 1820, historical phenomena such as European empires, the Rights of Woman, and slavery and abolition coincided with changes in print and media culture to produce the rich literary productions we will study. Through reading and graded assignments such as short essays and oral presentations, students will learn methods for analyzing the formal features of literary texts (such as narrative structure and poetic rhythm) and how such texts respond to the pressures of history. Furthermore, students will develop their ability to think critically about race and gender, to argue persuasively, and to express ideas clearly. Examples of readings include Aphra Behn's *Ooronoko*, Jonathan Swift's "The Lady's Dressing Room," Jane Austen's *Mansfield Park*, Mary Prince's *The History of Mary Prince*, and William Wordsworth's "To Toussaint L'Ouverture." Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-204 Race, Ethnicity, Controversy

Intermittent: 9 units

Coverage of police violence. Condemnations of Critical Race Theory. Book bans. "Kung flu." In recent years, current issues around race have proliferated, and with them, complex layers of discourse and controversy. This course examines current issues around race through the twin lenses of rhetoric and ethnic studies, asking how power is expressed through rhetorics of race and controversy. What are the communicative practices involved in framing or responding to racial violence, prejudice, and controversy? How do these practices harness various cultural, political, and historical forces, and to what effect? How do these discourses contribute to racialization, and where, and how, are differential distributions of power being expressed? We will seek to understand discourses around these issues and the backgrounds of various debates, from policing and abolition, to recurring anti-Asian racism, to affirmative action debates, to transracial adoption. Students will learn to analyze discourses around race rhetorically, identify structures of power at work in these discourses, and produce a final paper analyzing the rhetorics of a current issue or controversy around race. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-206 Intro to Creative Writing

Intermittent: 9 units

In this course we will explore how stories work and why we tell them. Using screenplays, short fiction and personal essays, we will analyze how narratives function and how, upon reflection, narratives often function in very similar ways no matter what the genre. Storytelling has a shape. It dominates the way all stories are told and can be traced back in history to the very beginning of the recorded word. We will study traditional structure in screenplays and contemporary prose pieces, and consider stories from fairy tales to serialized television shows. These master texts will be used to guide the students as they write and develop their own stories.

76-207 Special Topics in Literature & Culture

Intermittent: 9 units

Topics vary by semester and section. For Fall 2023 section descriptions, visit the course URL.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: <https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSjver61zYwMb2GfFYzS7zFdxzMyH6lg/edit?usp=sharing> (<https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSjver61zYwMb2GfFYzS7zFdxzMyH6lg/edit?usp=sharing>)

76-210 Banned Books

Fall: 9 units

Literature is powerful! Indeed, we're interested in books that are so controversial that people will shout, argue, and try to change laws in order to have a book removed from a curriculum, a school or public library, or a prison. At the same time we'll learn about how, in response, other people work extremely hard to defend books against removal and censorship. The term "banned books," can be a bit misleading in the US context; only in very rare cases does the US federal government get involved in trying to ban or censor a published work. Nonetheless, the US is a hot spot for those who seek to attack books, and for those who seek to defend them. In this course you will find that the actions of attackers and the actions of defenders are often mutually reinforcing. Every student in this course will contribute to a public facing website called The CMU Banned Books project. This website is used by journalists, scholars and activists around the world. This semester's books for reading and discussion include some of the most frequently banned and challenged books of the last five years, including *The Handmaid's Tale*, *Gender Queer*, *The 1619 Project*, and *The Absolutely True Diary of a Part-Time Indian*. Since 2020, organizations that track book banning tell us that the numbers of books banned and/or challenged are at an all-time high.

76-214 Understanding Cultural Complexities

Fall and Spring: 9 units

In today's society that explores Diversity, Equity, and Inclusion, one can ponder if Arab societies have made progress to achieve DEI towards minorities of religions (Muslims, Christians, Jews), sects (Sunni and Shi'a), ethnicities (Copts, Nubians, Kurds), Palestinians in Israel, homosexuals, and physical disabilities. This course aims to enrich students' understanding of the diversity of Arab countries and histories of intercommunal relations and conflict, explore the progress made in equating minorities to majorities, including them in various sectors, and granting them more rights. We will use readings, films, arts, and music, to engage with students in 4 Arab countries to further their learning.

76-217 Literature & Culture of the 20th and 21st Century

Intermittent: 9 units

Spring 2022: If you're in college now, you're probably a member of "Generation Z." There are a number of studies of Generation Z and its disposition, habits, and interests. While we are familiar with factors that make up our identities and #8212;nationality, race, ethnicity, gender, sexuality, income, and abledness and #8212;one's generation is probably just as influential, and according to some sociologists, more important than those other factors. In this class we will look at portraits of American generations in fiction, from the Baby Boomers and Generation X through Millennials and Generation Z. We will also look at some of the sociology and see how it bears on the fiction. In addition, we might look back at past generations, such as the generation that came of age after World War I, the Lost Generation, which inspired writers such as F. Scott Fitzgerald, and the Beat Generation, which inspired Jack Kerouac. In more recent fiction, we might read fiction such as Coupland's *Generation X*, Lauren Groff's portrait of the sixties generation in *Arcadia*, or Ling Ma's portrait of Millennials in *Severance*. We will also look at film along with novels, possibly including *The Big Chill*, *Reality Bites*, and other movies.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-219 Law & Blame

Intermittent: 9 units

How do we use language to accuse and defend? How do we attribute responsibility to specific individuals or institutions and dispute such claims, either by debunking them or shifting the blame? What makes the stories we tell and the arguments we make about responsibility succeed or fail? What unintended consequences can they produce and for what groups? This course will examine these and related questions through the lens of legal cases in which individuals or institutions are accused of responsibility for harm, from vehicular accident cases to criminal trials. The study of these questions is not only valuable for understanding the legal process, participating in it, or writing about it, but the practice of attributing responsibility is common in many social and institutional contexts beyond law, even in daily conversation. The course explores fundamental questions about culture, ethics, and politics, including issues involving systematic and structural inequalities involving race, class, gender, sexual orientation, religion, and national origin, which are evident both in the legal cases studied and in the public imagination and controversy beyond the courtroom. The societal implications explored include inequitable constraints on freedom in criminal justice and economic inequalities perpetuated through civil lawsuits, as well as inequalities in cultural power and status in the ways some voices are recognized in the legal process and others are not. Drawing on readings from rhetoric, linguistics, and legal studies, as well as briefs, opening and closing arguments, direct and cross-examinations of witnesses, physical and documentary evidence, and judicial opinions from legal cases, we will examine the strategies advocates use to attribute responsibility, enhance equity, and manage such disputes.

76-221 Books You Should Have Read By Now

Fall and Spring: 9 units

Topics vary by semester and section. Fall 2023: Medical Triumphs and Transgressions - How can literary stories enable us to understand the social possibilities and problems involved in medical advancement, research, and practice? What does good medical care look like does it focus on bodily wellbeing alone, or does it also account for psychological and socioeconomic dimensions of wellbeing? How do our social views shape and infiltrate medical discourse, and vice versa? In this class, we will read and discuss novels and occasional creative nonfiction works about a variety of topics: reproductive health and rights, psychiatric care, racial and gender discrimination in healthcare, advances in medical technology (including cloning and the use of human body parts in medical research), and more. We will examine how literature represents medicine's social impacts, revealing both hopes and anxieties about our contemporary world and its future. We will consider: What does the literature say about medicine's values, problems, and goals? What is at stake in medical advancement? Who gets to access medical care, and who experiences barriers?

76-223 Contemporary Black Literature

Spring: 9 units

This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the relationship between poetic forms and expressions of social and self-representation. However, this class will primarily focus on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. Authors include: W.E.B. DuBois, Zora Neale Hurston, James Baldwin, Zadie Smith, Claude McKay, Amiri Baraka, Franz Fanon, Marlon James, Edouard Glissant, Nnedi Okorafor, Merle Collins and Jamaica Kincaid to name a few.

76-230 Literature & Culture in the 19th Century

Intermittent: 9 units

Topics vary by semester. Fall 2023: Literature and Social Change - From the French Revolution to the beginning of the twentieth century, literature began to play an explosive role in the forces of political transition and the struggle for social justice. This course studies novels, poetry and prose in relation to both political and industrial revolutions during the rise of empire and capitalism and the road to climate change. We will study apocalyptic novels like Mary Shelley's *The Last Man* and novels of empire like *Jane Eyre* and its retelling in *Wide Sargasso Sea*; poetry about living in revolutionary times by Wordsworth and Phillis Wheatley Peters; and anti-capitalist anti-slavery writing such as Ottobah Cugoana's "Thoughts and Sentiments on the Evil of Slavery."

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-232 Introduction to Black Literature

Intermittent: 9 units

This course will take a transatlantic approach to what constitutes blackness as well as black literature and expression from the turn of the 20th century until the present. We will investigate the way authors and artists use literature and other mediums of expression for social and self-representation. Our primary focus will be on prose works (novels, memoirs and non-fiction essays) that span a multitude of genres from mystery to literary and science fiction. There will also be sections of the course that focus on other mediums such as visual art, comics, music, film and television. We will cover figures such as: Fredrick Douglass, W.E.B. DuBois, Zora Neale Hurston, Langston Hughes, Claude McKay, Amiri Baraka, Franz Fanon, Toni Morrison, Merle Collins, Kyle Baker, Kara Walker and Beyonce to name a few.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-233 Literature and Culture in the Renaissance

Intermittent: 9 units

Combining theology, politics, history, and art, this course begins with the question that preoccupied English Renaissance (1500-1700) writers: how should power be represented? The course will look at how canonical poets including Sidney, Shakespeare, Donne, and Milton depicted angels and diplomats and how such images combined with writers' ideas of linguistic, political, and sexual power. Among topics we will likely consider are the linguistic contract, mediation, gender, non-binary identities, immunity, license, infidelity, automation, accommodation, and representation of popular sovereignty.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-236 Major Fiction Then and Now

Intermittent: 9 units

We read newspapers for reports about what is happening in our world. But we also read fiction and #8212;novels and stories and #8212;that tell us about imaginary worlds. Sometimes they are very much like our world, sometimes different. In this course we'll read classic novels like Charles Dickens' *Great Expectations* or Dostoyevsky's *Crime and Punishment* up to contemporary ones like *Station Eleven* or *Severance*. We will consider how they represent the world, their use of literary forms, and how they lead us into their alterior world. We will also consider what they say about their culture and society. Do they make a statement about the world, or are they more for entertainment? This course is based on the Inside-Out Prison Exchange Program, and will be taught at SCI Somerset, a nearby prison. The course will include both "outside" students from CMU, as well as "inside" students at SCI Somerset. The course focuses on active participation and discussion between students. It runs from 2:30-5:10 on Friday afternoon. CMU students will travel together by bus, leaving our campus at 12:30 and returning by 6:30. To enroll, students in the course will submit a brief application and interview with faculty. The course is part of an exciting new initiative by CMU to bring education into America's prisons.

76-238 What Was the Hip-Hop Generation?

Intermittent: 9 units

This course will attempt to answer a simply stated but not so simply answered question: What is (or was) the "hip-hop" generation? Bakari Kitwana gives us a very broad but useful rubric to understand whom that generation was in his 2002 book, *The Hip-Hop Generation: Young Blacks and the Crisis of African-American Culture*. For Kitwana it defines the first generation of African-American youth that grew up in post-segregation America. While useful, Kitwana's definition is also quite provocative since many of the earliest practitioners (and consumers) of what would eventually be called "hip-hop" were not all African-Americans but Greeks, Puerto Ricans, Jews, Jamaicans, Germans, Trinidadians, Mexicans, etc..., many of whom lived in America but also encountered hip-hop elsewhere on the planet. In our class we will take a broad, global perspective on the question of "what is/was the hip-hop generation" through scholarly and popular works by Kitwana, Jeff Chang, Tricia Rose and many others. Given the significant media studies components of this course our class will lean heavily on musical, cinematic and televisual sources. Not only will you watch early fictional films about hip-hop like *Wildstyle* and *Krush Groove* but others like *Matthieu Kassovitz's La Haine* and *Rick Famuyimas Brown Sugar* which are influenced by hip-hop culture. We will also watch music videos as well as listen to singles and select albums like *Queen Latifah's All Hail the Queen*, *Kendrick Lamars To Pimp A Butterfly*, *Die Antwoords Tension* as well as read memoirs such as *Jay-Z's Decoded*.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-239 Introduction to Film Studies

Fall and Spring: 9 units

This course is an introduction to the history, technology, aesthetics, and ideology of film. Our main focus is the narrative fiction film, but we will also discuss documentaries, avant-garde work, and animation. The central organizing principle is historical, but there are a number of recurring thematic concerns. These include an examination of the basic principles of filmmaking, the development of film technology, the definition of film as both art and business, and the history of film as an object of critical and cultural study. The goals of this course are threefold. First, it will provide you with a solid grounding in the key issues and concepts of film studies. Second, it will expand your ability to knowledgeably critique individual cinematic works and their relationship to the larger culture. Lastly, it will provide you with experience in expressing your critiques in writing.

76-241 Introduction to Gender Studies

Fall and Spring: 9 units

Intersectional feminism. Structural oppression. Biological sex vs. gender roles. LGBTQIA+ rights. Consent. Masculinity. #metoo and gender-based violence. Sexual politics. Global feminism. This course offers students a scholarly introduction to these social and political issues through critical readings, literature and film. In this discussion-based class, students read and discuss contemporary gender studies that speaks to questions of identity, race, nation, sexuality, and disability. Critical readings include work by Audre Lorde, bell hooks, Judith Butler, Kimberl and #233; Crenshaw, Sara Ahmed, Eve Sedgwick, Raewyn Connell, Mari Matsuda, Mona Eltahawy, Rosemarie GarlandThomson, and Kate Bornstein. Fiction might include Toni Morrison, Ocean Vuong, and Alison Bechdel. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-242 American Woman Writers

Intermittent: 9 units

In 1855, Nathaniel Hawthorne lamented to his publisher that "America is now wholly given to a damned mob of scribbling women and I should have no chance of success while the public taste is occupied with their trash." Even today, *The New York Times Book Review* and other gatekeepers rarely give women writers the coverage that male writers receive. In this course we will trace the multiple traditions of 20th century American women's writing and examine how women writers question, resist, subvert, and revise traditional gender roles. Our readings will address: the social construction of gender; the relationship between gender and genre; the cultural positions of women as writers and readers; women's rights and suffrage; women and work; female sexuality and sexual freedom; constructions of motherhood; intersections of gender with race, class, and ethnicity. Readings include: *The House of Mirth*, *Pale Horse Pale Rider*, *Their Eyes Were Watching God*, *Raisin in the Sun*, *To be Young, Gifted and Black*, *Woman Warrior*, *Fun Home*, and *The Namesake*. Every other week (or so) we will be reading excerpts from *Feminist Literary Theory and Criticism*.

76-243 Introduction to Television

Intermittent: 9 units

Television is a ubiquitous vehicle of mass culture that cannot be casually dismissed or uncritically celebrated. This course approaches television as an industry, a global mass medium, and a site of social and political discourse. It will provide an overview of various critical frameworks for understanding television. It will contextualize the ways that television affects and mediates configurations of class, race, gender, and sexuality. We will also reflect on our viewing practices: from contemplation to binge-watching and guilty pleasures. To do this, the course will engage with a wide variety of popular American TV genres and formats, including sitcoms, reality TV, dramas, and news and talk shows. It will also provide a historical overview of the medium. The course will conclude with the rise of digital streaming platforms and examine how they have impacted network television.

76-244 Immigrant Fictions

Intermittent: 9 units

Contemporary writers offer vibrant portrayals of questions around identity and belonging that accompany migration and immigration to the United States. Their works show how displaced people and their children reinvent themselves, even as they look back to other homelands. This contemporary literature course combines fiction, poetry, drama and scholarly non-fiction readings to examine the experiences of the transnational movement of people to the United States, including international students, refugees, and documented and undocumented migrants and their families. We will consider not only the experience of personal migration, but also the global social, economic and political processes that structure that movement. Possible fiction readings draws from Asian American studies, Latinx studies, and African American studies, and might include Jhumpa Lahiri, Valerie Luiselli, Chimamanda Adichie, Christina Garcia, Juno D and #237;az, Lisa Ko, Cathy Park Hong, and Edwidge Danticat. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-245 Shakespeare: Tragedies & Histories

Spring: 9 units

In the closing decades of the sixteenth century, enterprising cultural producers in early modern London began to develop a new commercial venture called 'playing': a business that offered ordinary people a few hours of dramatic entertainment for the price of one penny. In addition to watching the professional players onstage, spectators also participated in a form of play themselves (in a sense) because theatrical experience provided a unique opportunity to engage imaginatively with otherwise inaccessible people, worlds, and ideas. More than four hundred years later, the drama of the period now ranks among the most esteemed texts in all English literature, and the name 'Shakespeare' has become a byword for literary genius. This course will offer an overview of Shakespeare's tragedies and histories. As we read through these works, we will endeavor to understand what, and how, they meant in their original context, thereby developing a historically informed perspective on their influence over our own cultural landscape.

76-247 Shakespeare: Comedies and Romances

Fall: 9 units

Sometime around the late sixteenth century, enterprising cultural producers in early modern London began to develop a new commercial venture called 'playing': a business that offered ordinary people a few hours of dramatic entertainment for the price of one penny. In addition to watching the professional players onstage, spectators also participated in a form of play themselves, in a sense, because theatrical experience provided a unique opportunity to engage imaginatively with otherwise inaccessible people, worlds, and ideas. More than four hundred years later, the drama of the period now ranks among the most esteemed texts in all English literature, and the name 'Shakespeare' has become a byword for literary genius. This course will offer a selection of Shakespeare's delightful and sometimes surprisingly edgy comedies and late romances. As we read through these works, we will endeavor to understand what, and how, they meant in their original context, thereby developing a historically informed perspective on their influence over our own cultural landscape.

76-251 Exploring Creative Writing in Community

Intermittent: 9 units

This creative writing course will be taught in a prison. Students will read and write and be in conversation with incarcerated men in Somerset, PA. The course will expose students to all three genres of creative writing, and will require intensive reading. Transportation will be provided, but since the prison is an hour and a half away, students need to be willing to dedicate an entire Friday and #8212; leaving at 12:30 and returning at 7:00pm. This course is based on the Inside-Out Prison Exchange Program, and will be taught at SCI Somerset, a nearby prison.

76-253 Information Graphics

Intermittent: 3 units

This micro-course introduces the basics of designing information graphics to students in all disciplines who are interested in learning to communicate complex information clearly and ethically using information graphics. Information graphics are ubiquitous. They are used by both practitioners and academics across many disciplines to communicate complex ideas, processes, and systems. While millions of decisions are made based on information graphics daily, creating an effective graphic is not simple. Designing information graphics requires careful consideration from multiple perspectives, including visual perception, social psychology, semiotics, and design ethics. What makes information graphics effective? What is required to optimize the design of an information graphic? How should information graphics be evaluated? Can information graphics be neutral, without bias? In this introductory course, we will address these and other questions through a hands-on project and discussions on various threads of studies around the analysis of information graphics. Assigned readings will complement the projects allowing students to examine information graphics from the perspectives of relevant theories and research findings. Class discussions and critiques are an essential part of this course. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-259 Film History

Fall: 9 units

This introductory course will focus on the history of the American film industry, 1930-1980. On most weeks, we will screen two films that reflect the most important genres and most enduring achievements of the era. We will be concerned with understanding how the studio system produced and marketed these works, and how that system changed significantly from the 1950s-1970s. By focusing on individual studios (for example, MGM and Warner Bros.) as "test cases," the class will also examine how particular companies produced films of a certain type in terms of such parameters as genre, theme, player, class address, and/or style. Readings will deal with the history of Hollywood, the various films, stars and/or filmmakers considered, as well theoretical/critical issues such as authorship, reception, and high vs. low culture. Students will learn important skills for film history, including reception study, archival research, and contextual analysis. Grades will be based on three papers that require different kinds of historical research, a midterm, and a final.

Prerequisite: 76-239

76-260 Introduction to Writing Fiction

Fall and Spring: 9 units

This is an introduction to the reading and writing of short fiction. Character development and the creation of scenes will be the principal goals in the writing of short stories during the course of the semester. Revisions of the stories will constitute a major part of the final grade. Reading assignments will illustrate the different elements of fiction reviewed and practiced, and students will analyze and discuss stories from a writer's point of view.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-261 Introduction to Writing Creative Nonfiction

Intermittent: 9 units

In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective nonfiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by nonfiction writing. What is the nonfiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives nonfiction writing integrity? What does the term "creative nonfiction" mean? How have the form and aims of nonfiction writing - from memoir to essays to long-form journalism - evolved for better and for worse?

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-265 Introduction to Writing Poetry

Fall and Spring: 9 units

This course is meant to serve as an introduction to the craft of poetry. We'll look closely at traditional forms in an effort to understand the effects of more formal choices on the page, and we'll examine the craft choices of modern and contemporary poets to expand our understanding of poetic approaches. Our analysis of poetry will begin at the level of the syllable and progress to words, lines, stanzas, series, and collections. You will be required to read both published work and the work of your classmates with a critical eye, to write your own poems, both formal and not, to write several short analysis essays, to write a longer critical essay, and to demonstrate your knowledge on one in-class exam. The most important take-away from this class is the ability to talk knowledgeably and critically about poetry. What you learn here will pave the way for your future as both a writer and a reader.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

Course Website: <https://docs.google.com/document/d/1AGv7lx7ovF0FSajw8-Sx5ekefMYdNPkr5qv0GnijjEg/edit?usp=sharing> (<https://docs.google.com/document/d/1AGv7lx7ovF0FSajw8-Sx5ekefMYdNPkr5qv0GnijjEg/edit?usp=sharing>)

76-269 Introduction to Screenwriting

Fall and Spring: 9 units

This is a course in screenplay narrative. The screenplay has a certain format observed by every screenwriter. It is not so difficult to learn the format. The difficulty is in developing a screen story populated by believable characters, creating an expressive and logical relationship between the scenes by manipulating screen space and screen time (knowing what to omit from the story and what to emphasize), and finally writing dialogue that sounds real, but that does not simply copy everyday speech. The class will be structured into weekly writing exercises, discussion of the narratives under consideration, presentation and discussion of student work, and a final writing project.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-270 Writing for the Professions

All Semesters: 9 units

Writing in the Professions is a writing course specifically designed for mainly sophomores and juniors (although it is relevant for some freshmen and seniors) in all majors other than English. The course is appropriate for upper-level students in all CMU colleges and assumes that you may not have had much college-level writing instruction past your first year. The basic idea of the course is to give you experience in developing the writing skills you will be expected to have as you make the transition from student to professional. The course will cover some foundational principles of designing multimodal writing and communication within a variety of tasks including resume and cover letter writing, proposal writing and writing instructions. Students will discern the difference between writing for general and specific audiences, and analysis of visual aids in various texts. The course requires that students work both independently and in groups.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: <https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/index.html> (<https://www.cmu.edu/dietrich/english/academic-programs/writing-and-communication/>)

76-271 Introduction to Professional and Technical Writing

Spring: 9 units

Professional and technical communicators use words and images to connect people with information. With a strong foundation in rhetoric, this course will sharpen your abilities to communicate information clearly, effectively, and responsibly to real readers, stakeholders, and decision makers. Our assignments and conversations will include a wide range of genres and rhetorical situations you can expect to encounter as a professional and technical communicator, including job application genres, narrative genres like feature articles that blend subject matter interviews with keen observation, research genres like proposals, and team writing genres like technical documentation. A high level goal for the course is to combine theory, methods, and best practices for putting real readers and users of information at the center of our communication strategies. By the end of the course, you will have a portfolio of polished work that you can use to narrate your professional strengths and interests. This course is designed for undergraduates pursuing majors and minors in a writing and communication field, and who want to explore professional and technical communication as a discipline and career area.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-275 Introduction to Critical Writing

Fall: 9 units

(This course was formerly titled Critical Writing Workshop.) The goal of this course is to sharpen your ability to read and write about literary and other imaginative works. Critical reading and writing mean gathering and evaluating language and images to form an interpretation of a print, visual, or other media text. To that end, you will learn analytical keywords and terms from literary and cultural theory and how to apply them to texts and other objects. The focus will be on theories of race and gender and how they inform literary texts and our reading of them. Our course's method for critical writing instruction will be to workshop drafts of your essays. To that end, you will write four short interpretive papers in the course. You will also gain practice at oral presentation, peer-review and critique. To help us fine tune and integrate our critical skills we will spend the semester writing and thinking through genre, the categories by which we name and understand literature, and other media. Since this is a writing workshop and our time for reading will be somewhat limited, we are focusing on "the gothic" and its literary legacies from the 18th into the 20th century. The communication and analytic skills you acquire in this class will transfer to your work in a wide range of academic disciplines and professional contexts.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-278 Japanese Film and Literature: The Art of Storytelling

Intermittent: 9 units

This course explores how the art of storytelling is in tandem with the vicissitudes of the human condition as illustrated in Japan's variety of fictions, non-fictions, and films in the twentieth and twenty-first centuries. Analyses of each storytelling not only reveal the cultural dynamics behind Japanese modernity, but also invite students to find new insights into Japanese culture and their ways of perceiving our globalized world. What kind of cultural exchanges took place between modern Japan and the West? How are Japan's traditional values transformed in the face of modern technicalization and industrialization, compared to the modernization of other countries? And, in turn, what kind of impact has modern Japanese culture had on today's world? Tackling these questions among others, the course also extends to such issues as the legacy of traditional Japanese culture, the modern Emperor system, World War II experiences, emerging voices of minorities, and popular culture (e.g., anime and subculture).

76-280 Gender and Sexuality in Performance

Intermittent: 9 units

"Performance" describes a wide range of practices, from the everyday to the artistic. Gender and sexuality are key elements in everyday, political, and artistic performances, from the very personal how you order a latte at Tassa D'Oro, tell a lover goodbye at the airport or comfort a crying child to the very public performing a Bach cello suite or an iconic King Lear, staging a demonstration against police violence or marketing a new app. This course will bring performance and theory into a practical partnership to create and critique social and individual narratives. We will also take an intersectional approach to gender and sexuality, mindfully mapping these performances in relation to race, class, and ability. We raise questions such as, How does everyday performance define gender and sexual identity? How do gender and sexuality define everyday performance? How does aesthetic performance art, theater, film, digital media, poetry intervene in the ways in which gender and sexuality are performed? Readings in theory at the intersection between gender studies, queer theory, intersectional feminism, and performance studies will help us explore these questions. We will also consider a variety of cultural and artistic practices. Since this class will be in a remote format, we will focus on performances that are digitally accessible, both for the performances that we study and those we create for the class. This course counts towards the Gender Studies Minor.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-282 Disability in Pop Culture

All Semesters: 9 units

In 2016, ABC debuted the show *Speechless*, which follows the life of JJ, a high school teenager with cerebral palsy. In 2015, Deaf West Theatre premiered a revival production of *Spring Awakening* on Broadway, debuting a cast of both deaf and hearing actors who performed the show using American Sign Language and English simultaneously. In 2013, Allie Brosh released a book version of her blog titled *Hyperbole and a Half: Unfortunate Situations, Flawed Coping Mechanisms, Mayhem, and Other Things That Happened* a combination of web comics and stories that included discussions of depression. These examples are a mere few of more recent representations of disability in pop culture. In this course, we will investigate how representations of disability tell stories about difference. Using the tools of rhetorical analysis, we will ask the following questions: How do memoirs, films, comics, health initiatives, advertisements, blogs, laws, and poetry use language and images to influence or construct our understanding of disability? How do these representations engage differences of gender, race, class, and sexuality? And finally, how does this work expand broader cultural, aesthetic, and political views of embodiment, disability, and difference? This course has two major parts: 1) We will examine various models of disability in order to theorize concepts such as normal, the gaze, passing, and access. In the process, we will consider how these concepts intersect with gender, race, class, and sexuality. 2) We will engage these theories through close reading of actual representations of disability that circulate in our worlds around us and shape our understandings of disability. We will pay particular attention to the rhetorical elements central to these representations such as purpose, genre, audience, context, form, and style.

76-286 Oral Communication

Intermittent: 6 units

Oral presentations are essential to professional success. Yet many people find themselves growing weak in the knees at the thought of presenting in front of a group. They read off of notes, speak too fast, or pepper their speech with nervous filler words such as "um" or "you know." 76-286 Oral Presentations is a mini intended for students who want to boost their confidence in presenting in front of others. You will learn strategies for structuring the content of a presentation, designing effective presentation slides, and controlling your voice and body language to produce a smooth, confident-sounding oral delivery. We will begin with giving short informal presentations and gradually increase the stakes as your confidence improves. You will have weekly opportunities to practice and improve your skills. We will also find opportunities to practice in a variety of physical settings so you can envision yourself as a calm, confident speaker no matter your surroundings. Grades in the course will be based on improvement and effort to encourage students to focus on their development rather than on final outcomes.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-287 Sex & Texts

Intermittent: 9 units

Please see *Content Warning* Below In this course, we will consider how writing and communication serve as means to create, define, and bound our worlds, shaping our ideas about "sex" and "sexuality" at their intersections with gender, disability, race, geographic location, religion, age, and so on. Using a rhetorical perspective, we will interrogate how everyday experiences with and performances of sex and sexuality are tied to legal, medical, corporate, cultural, and historical practices and ideologies. Readings will consist of public, scholarly, and creative genres such as Roxane Gay's *Unruly Bodies*, Judith Butler's *Gender Trouble*, Cardi B's "WAP" (feat. Megan Thee Stallion), and the Hulu series *Shrill* and will address topics including but not limited to bathroom bills, rape culture, the beauty industry, intellectual property, citizenship, and marriage equality. Students in this course will 1) develop a vocabulary for talking about sex and sexuality; 2) examine how sex and sexuality are shaped by public, historical, and cultural norms; and 3) practice analyzing rhetorical elements such as purpose, genre, audience, context, form, and style. Student projects will include weekly discussion posts, two shorter papers, and one creative project. This course meets the Dietrich College Communicative Gen Ed requirement. *Content Warning* Because this course takes up questions of sex and sexuality, we will discuss the body/embodiment and issues related to violence (sexual, racial, intellectual, domestic, linguistic, etc.). While projects will ask students to examine questions of sex and sexuality, students will not be required to write about issues related to violence.

76-289 Bilingual & Bicultural Experiences in the US

Intermittent: 9 units

What does it mean to be bilingual in the USA, when approximately 80% of Americans are monolingual English-speakers? In this course, we will learn about the nature and experience of bilingualism and biculturalism (past and present) and how it shapes different perspectives and worldviews and #8212;within an individual, between individuals, and on a larger (societal, cultural) level. The course highlights the experiences of groups such as immigrants, racial/ethnic minorities, indigenous communities, and users of signed languages to foreground experiences that may be similar to or different from those of the students. We use a variety of resources (e.g., social media, film and documentaries, historical documents, literature, music, art) to accomplish this, and students are encouraged to be creative in the ways they design their own hands-on projects. This discussion-based course is taught in English and is open to all students, whether they identify as bilingual/bicultural, or are simply interested in the course topic.

76-290 Literature & Culture in the 20th Century

Intermittent: 9 units

Topics vary by semester and instructor. For example: Spring 2020: Black Fiction This course will take a transatlantic approach to what constitutes black literature and artistic expression from the nineteenth until the early twenty-first century. We will investigate how black authors use literature and other mediums of expression for social, political and self-presentation. Our primary focus will be on fiction with some memoir, poetry and non-fiction essays thrown into the mix. We will cover canonical black writers of the diaspora as well as key literary periods and movements. Along with these more conventional ways of accounting for literary history we will look at the way gender, sexuality, (trans) national belonging, ideology and political economy shape the reception, aesthetics and context of black writing. Authors covered in this course include: Fredrick Douglass, Nella Larson, Audre Lorde, Ralph Ellison, Melvin Tolson, Percival Everett, Merle Collins, Claudia Rankine and Tayari Jones to name a few. Prerequisites: 76-101 or 76-102 or (76-106 and 76-108) or (76-106 and 76-107) or (76-107 and 76-108)

76-291 Getting Heard/Making a Difference

Intermittent: 9 units

How can a college student get people to pay attention to a problem, whether it is a personal, social, environmental, ethical, or public issue? In particular, how do people who don't already have what is called "standing" such as the authority or credentials to speak get their community to listen? In this course you will learn how to create real dialogue and carry out effective (not simply adversarial) engagement within a university and later in your professional lives. It introduces you to the rhetorical art of savvy, issue-centered social engagement. Drawing on research, theory, and our own campus investigation, we will try out methods for collecting competing perspectives, for framing a shared actionable problem, and for creating well-supported, persuasive and motivating accounts in proposals, reports, editorials, stories, or media. The theory and strategies we study are designed to create what is called a rhetorical presence for your ideas, to put them into circulation, and help create a more engaged local public. This course meets the Dietrich College Communicative Gen Ed requirement.

76-292 Introduction to Film Production

Fall: 9 units

This course is an introduction to the process of filmmaking. Students will develop a personal cinematic language and create a short final film from the ideation, to the synopsis and shot list, the set then to the editing room. The course will introduce technical tools to create audio and visual forms that serve the content developed in a film treatment through filming assignments, planning and producing a short film, peer review and group work. The focus will be on understanding shots and coverage of a scene, the various aspects of the cinematic language, with an emphasis on the basic visual components such as space, movement, and rhythm - and how they are used to tell the story visually. Audio layering to create a meaningful soundscape and the art of Editing will be discussed extensively. Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-293 Writing about Research in Your Discipline

Intermittent: 9 units

This course introduces the characteristics and types of writing required of students at advanced undergraduate and beginning graduate levels while building sentence-level editing skills. Topics addressed include the role of writing in the academy, the writing process including editing and revision strategies, expectations for content associated with different genres, bibliographic styles and reference management software, and an introduction to the reporting of empirical research. Students will work through modules on sentence structures associated with academic language as well as workshop their own writing projects. This course is appropriate for students considering writing a senior thesis and/or applying to graduate school.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

Course Website: <https://www.cmu.edu/dietrich/english/courses/fall-2020-course-descriptions.pdf>

76-295 Russian Cinema: From the Bolshevik Revolution to Putin's Russia

Fall: 9 units

"Last night I was in the kingdom of shadows," said the writer Maxim Gorky in 1896 after seeing a film for the first time. "How terrifying to be there!" Early film inspired fear and fascination in its Russian audiences, and before long became a medium of bold aesthetic and philosophical experimentation. This seminar-style course surveys the development of Russian and Soviet film, paying equal attention to the formal evolution of the medium and the circumstances historical, cultural, institutional that shaped it. We will examine Sergei Eisenstein's and Dziga Vertov's experiments with montage in light of the events of the Bolshevik Revolution and the directors' engagement with Marxism; Georgi Alexandrov's and the Vasiliev brothers' Socialist Realist production against the backdrop of Stalinist censorship; Andrei Tarkovsky's and Kira Muratova's Thaw-era films within the broader context of New Wave Cinema; and the works of contemporary directors, including Aleksei Balabanov, Alexander Sokurov, and Andrey Zvyagintsev, in connection with the shifting social and political landscape of post-Soviet Russia. Besides introducing students to the Russian and Soviet cinematic tradition, this course will hone their skills in close visual analysis. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

76-296 20th Century Russian Masterpieces

Intermittent: 9 units

At the beginning of the 20th century, the Russian Empire underwent a series of dramatic changes in quick succession: industrial modernization, the unsuccessful 1905 rebellion, terrible losses in the First World War, finally culminating in the 1917 October Revolution. The literature and culture of the era were deeply impacted by these upheavals as artists and writers of the era attempted to capture and convey the world rapidly shifting around them. This course will acquaint students with canonical texts from 20th-century Russian literature and will also examine the highly specific context in which they were produced. From the fin-de-siècle aesthetics of a crumbling Russian Empire to the avant-garde experimentalism of the Russian Revolution and Civil War era, to the establishment of Socialist Realism and the implementation of a Totalitarian regime under Stalin, the course invites students to think about both the realities of life and artistic production in a rapidly transforming country as well as the ways in which these works bring contemporary readers to the inner lives of Soviet citizens.

76-300 Professional Seminar

Fall: 3 units

This weekly, 3-unit seminar is designed to give professional and technical writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and is open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

76-301 Internship

All Semesters

This course is designed to help you explore possible writing-related careers as you gain workplace experience and earn academic credit. You'll work on- or off-campus as an entry-level professional writer for 8-10 hours per week in a field of interest to you (public relations, journalism, advertising, magazine writing, non-profit, healthcare, etc.). You are responsible for finding an internship. Most of your class time for the course will be completed at your internship site - a minimum of 120 hours (8-10 per week) over the semester for 9 units of credit. As the academic component of the course, you'll keep a reflective journal and meet periodically with the internship coordinator to discuss your internship and related professional issues. You must register for the course before the add/drop deadline of the semester in which you want to do your internship. Before you can register, you must contact the internship instructor listed above to express your interest in the course and to be cleared for registration. Credit for the internship course cannot be retroactively awarded for past internships.

76-302 Communication Support Tutoring Practicum

Fall

The Communication Support Practicum is designed to introduce students to communication scholarship and pedagogy as well as the methods and theories that inform them for the purpose of communication support and tutoring in CMU's Student Academic Success Center. Students will explore communication (written, oral, and visual) in multiple disciplines and genres with a focus on gaining knowledge and skills to respond to communicators and their texts. Lectures, discussion, and assignments will offer a chance to think critically about tutoring practices and the ideologies and values on which they are based as well as ways to challenge the bias inherent in them. There will be many occasions to reflect on and evaluate tutoring skills, observe others in tutoring situations, and practice a variety of methods that consider the different needs of communicators. Students will gain awareness of how various spaces, identities, technologies, and abilities inform textual production as well as how to create a meaningful response to meet the diverse needs.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: <https://www.cmu.edu/gcc/faqs/index.html> (<https://www.cmu.edu/gcc/faqs/>)

76-303 Independent Study in Creative Writing

All Semesters

An Independent Study course is a course taken with faculty supervision that goes beyond the courses offered in a particular area of interest. It should not duplicate a course offered in the regular schedule of classes. A student wishing to take an independent study needs to locate a faculty member whose research interests are close to the area of proposed study and meet with the faculty member to discuss whether it is something the faculty member is interested in doing. The department requires that the student and instructor submit a written contract (available in the English Department) detailing the expectations (description of course of study, readings, how often the student/faculty member will meet) and requirements for the completed independent study project (number and length of papers) and a time-line for completion of the work. You should think of this as developing the equivalent of a detailed course syllabus/schedule, and typically involves development of a bibliography of readings.

76-306 Editing and Publishing

Fall and Spring

Note: Registration in this course is by permission only. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.

76-307 Advanced Editing and Publishing

Fall and Spring

Note: Registration in this course is by permission only. In this course students will work closely with the editors of Carnegie Mellon University Press to learn many of the facets of producing books. These range from business management and marketing to the elements of editing, book design, and production.

Prerequisite: 76-306

76-308 Literary Journal Publishing

Intermittent

In this course, students will learn about the landscape of and publication process for literary journals in the United States. We will read a variety of literary journals in print and online, will host guest speakers, and will do a variety of hands-on activities related to editing and publishing. Students will gain experience by working on The Oakland Review, an international literary journal run out of CMU, in capacities as varied as editorial, design and production, or promotion. If you are interested in registering for this course, please go to the Course URL and fill out the questionnaire. Thank you.

Prerequisites: 76-260 or 76-265

Course Website: <https://form.jotform.com/CMUEnglish/literary-journal-publishing-course> (<https://form.jotform.com/CMUEnglish/literary-journal-publishing-course/>)

76-310 Advanced Studies in Film and Media

Spring: 9 units

This course will focus on several key technical components of filmmaking and the ways they function within the film text, as well as the ways they can be read as an indication of the underlying ideology of a work. Individual units of the course will concentrate on performance, production design, photography, editing and music. Films will be drawn from a variety of national cinemas from around the world. A primary goal of the course will be the development of skills useful for filmmaking, film analysis and scholarship. Students will engage in focused projects designed to facilitate the pedagogical goals of each unit.

Prerequisite: 76-239

76-311 Acting Out in the London Theatre

Intermittent: 9 units

More Londoners went to the theater between 1660 and 1800 than read novels or newspapers. The theater was THE social media of this formative period in the history of an English-speaking, urban public, and this course explores the power of the theater as a means of both social control and political resistance. Instead of taking a traditional "survey" approach to this period in the English theater, we will study a succession of "nights at the theater," specific performances of plays that happened on particularly eventful evenings when the playwhile significant was not the only important performance. The farewell turn of a beloved actor, the presence in the house of a visiting African prince, violent protest by audiences against a play, an actor or pretty much anything could charge that evening's performance of a play with meaning beyond the script. We will approach plays from this period historically by reading, viewing, and listening to print and visual documents and music that inform the historical moment of the play. Most importantly, we will workshop scripts in class in order to learn from performance how these plays conveyed the power relations of race, class, and gender both then and today.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-312 Crime and Justice in American Film

Intermittent: 9 units

Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as The Ox-Bow Incident, Out of the Past, 12 Angry Men, Young Mr. Lincoln, Brute Force, The Equalizer, Jack Reacher and Minority Report. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

76-313 Creative Visual Storytelling in Film Production

Intermittent: 9 units

Visual storytelling cuts to the heart of the filmmaking process, combining all elements of the craft to engage the viewer. Every picture is comprised of a story, visuals, and, sometimes, sounds. This class is about learning how to understand and control time-based images to better tell your story. We will learn essential skills for becoming a creative technological storyteller - how to think visually and aurally. Fundamental focus will be on understanding the basic visual components - using space, tone, line, shape, color, movement and rhythm- and how they are used to visually tell a story, define characters, communicate moods, emotions, thoughts and ideas. We often are not consciously aware of them within a film but are critical in establishing the relationship between story structure and visual structure. Through readings, film analysis, creative brainstorming, assignments and individual critiques this class will guide each student into translating their creative vision into a short final film.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-314 Data Stories

Fall: 9 units

Every dataset has a story. In the age of big data, it is vital to understand the unlikely casts of algorithms, data miners, researchers, data janitors, pirates, data brokers, financiers, etc. whose activities shape culture. This course will feature a range of "farm to table" data stories, some going back hundreds of years, and introduce students to resources and strategies for contextual research. It will explore cases such as the London cholera epidemic, Google Books, Netflix, the Oxford English Dictionary, the Strava map, and the Queen Nefertiti scan alongside several pieces of art and fiction that capture aspects of data stories typically obscured elsewhere. Research methods introduced will include book history, media archeology, history of information, infrastructure studies, ethnography, narratology, and digital forensics. Students will read scholarly articles, novels, journalism, and popular non-fiction; they will test algorithms; and they will develop individualized long-form research and writing projects informed by computational methods in data studies, journalism, and art.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-315 19th Century American Literature

Intermittent: 9 units

These days, it's pretty easy to get to Walden Pond. It's right off route 126 South (not too far from Concord) and there is a nice little farm stand there called the Farm at Walden Woods, where you can get corn and raspberries and freshly baked bread. In this class we'll go back in time to the Walden Pond of Thoreau's time, with a focus on the Green Nineteen and #8212;-writers and thinkers who considered the relationship between human civilization and the American wilderness (Thoreau, Emerson and Hawthorne). We will think about the interrelationship between the environment and nascent capitalist industries by reading the poetry and prose by young women who worked in the Lowell Mill (The Lowell Mill Offerings). We will also think about the environment in relation to two slave narratives (Douglass, The Slave Narrative of Frederick Douglass and Harriet A. Jacobs, Incidents in the Life of a Slave Girl. Finally we will consider the environmental consciousness of the two most important poets of the 19th century, Walt Whitman and Emily Dickinson. As for coursework, we will use the class to practice meditation, nature walks, and one group project in which you will design your own environmentally conscious Utopian community.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-316 Topics in Literature: Watching HBO's The Watchmen

Intermittent: 9 units

This course is centered on the graphic, social and political universe created by HBO's The Watchmen series. Course viewings/readings will include: the 9-episode HBO series from 2019, the original The Watchmen comic series from the 1980s, and various cultural influences on the HBO series, including the musical Oklahoma, and the 1930s era singing group the Ink Spots, whose hit, "I Don't Want to Set the World on Fire," is featured in the series. The course will include the intro to film studies text, Writing about Movies, and one of the goals of the course will be for students to write original, accessible, and interesting 1000 word essays about the series to be published on a public website.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-317 Contemporary American Fiction

Intermittent: 9 units

No one seems to know quite how to define contemporary American fiction. It's clear that fiction has changed since the 1960s and 70s, the heyday of postmodernism, but it's hard to pin down what characterizes the work that has come since. In this course, we will read a selection of American fiction from the 1980s to the present and try to get a sense of its main lines. In particular we'll look at the turn to "genre," the expansion to multicultural authors, and the return to realism. Also, we will consider how it relates to American society. Authors might include Chimamanda Ngozi Adichie, Alison Bechdel, Junot Díaz, Jennifer Egan, Chang-Rae Lee, Emily St. John Mandel, Weike Wang, and Colson Whitehead.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-318 Communicating in the Global Marketplace

Intermittent: 9 units

We live in an interconnected global world that presents us with many complex challenges and also rewards. Are you prepared for the challenge of working with professionals from all over the world, whether you are physically located in the United States or somewhere else on the globe? Speakers of the English language continue to grow in numbers, often at the detriment of other languages. Yet speaking the same language does not mean we share the same cultural values and beliefs, or that we even understand and are aware of other cultural values and beliefs. While English might be the language of many organizations and professional settings, globalization brings along several pressing questions: How can professional communicators maximize productive and respectful communication across cultural contexts, and avoid conflict without imposing a particular culture's norms? How can professional communicators contribute to shaping a workplace discourse that can reach a wide, diverse, global audience? How can professional global communication be effectively planned, measured, and improved? This course addresses these questions by explaining the specific ways in which our backgrounds (from personal to social and even national) influence professional and technical communication; the impact of globalization on the workplace, especially in times of crisis; and the ways in which we can rely on general concepts and principles in order to communicate effectively in specific international settings and situations.

Prerequisites: 76-272 or 76-271 or 76-270

76-319 Environmental Rhetoric

Fall: 9 units

Should you take a hike or seize the mic? Environmental rhetoric combines commitment with contention. We start by exploring its multiple discourses, from Muir's vision of conservation, to Leopold's introduction of ecology, to Carson's call for public action, to contemporary scientific research and competing public discussions. To uncover their hidden logic, we study rhetorical strategies first, for analyzing arguments (over issues such as wolves, clean water, or sustainable design), and then for communicating risk (in the face of climate change, fracking, as well as wind power). In response, this course will prepare you to act as a research-based rhetorical consultant for a group of your choice, analyzing the issues and arguments it faces, in order to propose a rhetorically effective response, supported by your own imaginative prototype of a brochure, web page, press release.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-322 Gender and Sexuality in Performance

Intermittent: 4.5 units

"Performance" describes a wide range of practices, from the everyday to the artistic. Gender and sexuality are key elements in everyday, political, and artistic performances, from the very personal how you order a latte at Tassa D'Oro, tell a lover goodbye at the airport or comfort a crying child to the very public performing a Bach cello suite or an iconic King Lear, staging a demonstration against police violence or marketing a new app. This course will be co-taught by a specialist in gender and queer theory and a practitioner of performance art. We plan to bring performance art and theory into a practical partnership in the creation and critique of social and individual narratives about gender and sexuality. How does everyday performance define gender and sexual identity? How do gender and sexuality define everyday performance? How does aesthetic performance art, theater, film, digital media, poetry intervene in the ways in which gender and sexuality are performed? Readings in theory at the intersection between gender studies and performance studies will help us explore these questions. We will also consider a variety of cultural and artistic practices. The addition of simple performance prompts and exercises for students to incorporate into their research will blur theory and studio practices. Students will be encouraged to practice their theories surrounding performance within the classroom and in public space.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-323 Text to Screen

Intermittent: 9 units

This course is an introduction to the fundamentals of narrative filmmaking and the attendant creative processes. Students will explore the symbiosis between film literature, visual storytelling, team building and the practical planning essentials universal to making film.

Prerequisite: 76-269

76-324 Topics in Rhetoric: Language and Place

Intermittent: 9 units

TBD

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-108 and 76-106)

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-325 Intertextuality

Spring; 9 units

What do we mean when we say that someone has "twisted" our words, or that our words have been "taken out of context"? Why is Martin Luther King Jr. best remembered for saying, "I have a dream," and not for saying, "War is the greatest plague that can affect humanity"? What are political "talking points" and how are they perpetuated? How does a claim (unfounded or not) become a fact? How does a fact become a myth? These are just some of the questions that we will consider. More specifically, this is a course in how meaning changes as texts created in one context and for specific purposes are repeated, cited, and used in other contexts and for other purposes, sometimes related and relevant, sometimes not. More technically, we'll be focusing on the rhetorical nature of intertextual discourse. Our goal will be to examine the ways that people of all kinds including politicians, journalists, and scientists strategically draw upon and transform the statements, arguments, and evidence of other people to promote their own viewpoints or purposes. We will begin by investigating scholarship that views language as an extended conversation in which people struggle to have their own voices heard, and other voices countered or even suppressed. Later, we will survey a number of studies that suggest how individuals and organizations recontextualize and reinterpret prior discourse for persuasive ends. More specifically, we will analyze how the micro-features of the language (for example, qualifications, evaluations, and attributions) are used to persuade audiences that certain assertions are (not) factual, that certain speakers are (not) authoritative, and that certain proposed actions are (un)desirable. Ultimately, you can conduct your own research on intertextual rhetoric on a topic of specific interest to your academic or professional goals.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-326 Contemporary Global Literature

Intermittent; 9 units

In this course, students will read, interpret, discuss and write about novels and short stories written in English in the past ten years by writers originally from Africa, South Asia, East Asia and the Caribbean. While these works represent the "large stories" of economic globalization, refugee migration, and ecological catastrophe, they are crafted around the "small stories" of love, longing, friendship and family. We will talk about both kinds of narratives, tracing the entanglements of one in the other. Students will reflect on the relationship between history, society and culture in a global context, situating the contemporary within the longer trajectories that mark the legacies of colonialism and imperialism. This course is virtual and almost entirely synchronous; barring unexpected situations, attendance is expected for what should be a lively class discussion.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-327 Equity & Communication: Strategies for Institutional Change

Intermittent; 9 units

Communication is always embedded in power relationships with unstated social rules that govern who is able to say what when. But communication also offers us a tool for rewriting oppressive social scripts. In this class, we will look both at inequities built into our communication and strategies for overturning these inequities. The focus will be on practical actions that you can take to improve your school, workplace, or extracurricular groups. Our readings will come from diverse sources and fields, including sociolinguistics, psychology, education, organizational communication, rhetoric, and writing studies. While our readings might occasionally depress (or enrage) you, the overall focus of the course will be optimistic, challenging you to imagine solutions to the problems we discuss.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-328 Introduction to Corpus Linguistics

Intermittent; 9 units

This is a hands-on, project-based class that will help students build a methodological toolkit for computer-based textual analysis. That toolkit will include methods for the collection of data, its processing via off-the-shelf software and some simple code, as well as its analysis using a variety of statistical techniques. In doing so, the class offers students the opportunity to engage in scientifically oriented inquiry, giving priority to the use of corpus evidence to answer research questions. The first part of the term will be devoted to introducing fundamental concepts and taking a bird's eye view of the potential application of corpus methods in domains like academic writing, technical communication, and social media. From there, students will initiate projects of their own choosing and develop them over the course of the semester. The goal is to acquaint students with the strengths and limitations of computer-based textual analysis and to provide them with the necessary foundational skills to design projects, to apply appropriate quantitative methods, and to report their results clearly and ethically to a variety of audiences. This class requires neither an advanced knowledge of statistics nor any previous coding experience, just a curiosity about language and the ways in which identifying patterns in language can help us solve problems and understand our world.

76-329 Performing Race in Early Modernity

Intermittent; 9 units

The earliest known use of the term "white" in reference to Europeans occurs in *The Triumphs of Truth*, a 1613 play by Shakespeare's contemporary, Thomas Middleton. In addition to suggesting an important connection between race and drama in 17th-century England, this simple historical note raises a range of questions that have a direct bearing on some of the most pressing issues of the 21st century: Where do ideas about race come from? By what processes do the distinctions of racial concepts emerge, evolve, calcify, and mutate? How does the conceptualization of race relate to media? How do racial representations bolster and conduct political power? In this course, we will broach these questions by taking a close look at the race-making function of drama in early modernity, a period when race was an inchoate, incipient concept, caught up with the emergence of colonialism, capitalism, and increasing interconnection between peoples, cultures, and worlds. As we think, read, and converse together, we will endeavor to come to terms with the problems and paradoxes of racial representation in the early modern theater, a forum that offered access to innovative, daring thinking about human equality and ethical responsibility, but was also a site for the perpetuation of hateful stereotypes and exploitative theories of white supremacy. In a wide-ranging survey of drama, historical documents, and contemporary criticism, we will work toward an understanding of how race-based concepts operated in the theater, and how the drama early of modernity continues to influence thinking about race in our own time. This course meets the Dietrich College Reflecting Gen Ed requirement.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-331 Dissenters and Believers: Romantics, Revolution, and Religions

Intermittent; 9 units

This course examines the relation of Romantic writing to religion in the age of revolutions. We will read a number of Romantic-age writers: William Blake, S. T. Coleridge, William Wordsworth, Edmund Burke, Monk Lewis, Percy Shelley and #8212; in relation to the most "orthodox" religious modes (Anglican, Catholic, Lutheran, and Evangelical) and the most "heterodox" (Enthusiasm, Rational Dissent, Unitarianism, Deism, Pantheism, or atheism). We will also distinguish between "religions" (as formally institutionalized) and "religiosity" (defining religiosity as more diffused or displaced feelings, ideas and practices that are often not clearly marked as religious or related to any one institutional religion. Two papers are required.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-332 Writing about Research in Your Discipline

Intermittent: 9 units

This course introduces the characteristics and types of writing required of students at advanced undergraduate and beginning graduate levels while building sentence-level editing skills. Topics addressed include the role of writing in the academy, the writing process including editing and revision strategies, expectations for content associated with different genres, bibliographic styles and reference management software, and an introduction to the reporting of empirical research. Students will work through modules on sentence structures associated with academic language as well as workshop their own writing projects. This course is appropriate for students considering writing a senior thesis and/or applying to graduate school.

Prerequisite: 76-101

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>**76-333 Race and Controversy in the Arts**

Intermittent: 9 units

In the last three years, social media platforms have given artists and consumers of art an unprecedented platform to engage with the commercial art world as both activists and critics. 2017's trending hashtag #oscarswhite remarked on long-standing issues of inclusion within commercial filmmaking in the United States. Twitter also spread news from art worlds that were not always in the limelight; like Dana Schultz's painting "Open Casket" at the Whitney Biennial or Kenneth Goldsmith found poem "The Body of Michael Brown", read at an obscure conference at Brown University. Our course will put these and other controversies surrounding the politics of representation in the arts into broader historical and artistic contexts. We will approach the topic through particular case studies - from The Merchant of Venice to 2 Live Crew's obscenity trial - that highlight the confluence of social, political and artistic forces that frame these controversial works.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-335 20th and 21st Century American Fiction

Intermittent: 9 units

This course will examine American fiction from 1900 to the present. It will cover the movement from modernism, through midcentury realism and postmodernism, to the contemporary. We will look at scholarly definitions of those modes, as well as some of the cultural context that has informed American literature. Some of the authors will include modernists like Stein and Faulkner; midcentury writers and postmodernists like Ellison, McCarthy, and Pynchon; and contemporary writers like Diaz, Lahiri, and Franzen.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-337 Intersectional Feminism

Intermittent: 9 units

The concept of intersectionality first appeared in African-American feminist legal theory, but it rapidly spoke to other ideas and movements authored by other women positioned on the margins in the United States and beyond. Now widely disseminated as a feminist practice embraced by many identities, intersectional feminism acknowledges how interlocking power structures produce systematic oppression and discrimination to create distinctive gender identities in terms of such aspects as sexuality, race, ethnicity, class, religion, language (and accent), and neuro- and physical diversity. In this class, we will consider a wide variety of texts that mobilize this movement, including fiction, poetry, memoir, scholarly works, drama, popular media and films. We will consider voices from the "global south," non-Western countries that are speaking back to the economic and political centers of globalization. Pairing analysis with these texts with some examples of praxis, or political practice, we will think through and debate how critiques of power can move toward social change. Students will be encouraged to use these texts and a series of shorter writing assignments about texts to build toward a final project relevant to their own discipline. Readings might include Kimberlè #233; Crenshaw, Audre Lorde, bell hooks, Roxane Gay, Chimamanda Ngozi Adichie, Mona Eltahawy, Erika L. S and #225;nchez, Chandra Talpade Mohanty, Fatima Mernissi and Mari Matsuda, Fatima Mernissi, and Aiwah Ong.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-338 Internship Mini

Intermittent

This course is designed to help you explore possible writing-related careers as you gain workplace experience and earn academic credit. You'll work on- or off-campus as an entry-level professional writer in a field of interest to you (public relations, journalism, advertising, magazine writing, non-profit, healthcare, etc.). You are responsible for finding an internship. Most of your class time for the course will be completed at your internship site. As the academic component of the course, you'll keep a reflective journal and meet periodically with the internship coordinator to discuss your internship and related professional issues. You must register for the course before the add/drop deadline of the semester in which you want to do your internship. Before you can register, you must contact the internship instructor listed above to express your interest in the course and to be cleared for registration. Credit for the internship course cannot be retroactively awarded for past internships.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-339 Topics in Film and Media

Intermittent: 9 units

Topics vary by semester and section. For Fall 2023 section descriptions, visit the course URL.

Prerequisites: 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

Course Website: <https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSjver61zYwMb2GfFyZ57zFdxzMyH6lg/edit?usp=sharing> (<https://docs.google.com/spreadsheets/d/1HzTjLjBFM73kSjver61zYwMb2GfFyZ57zFdxzMyH6lg/edit?usp=sharing>)

76-341 Race & Gender in the Age of Jane Austen

Intermittent: 9 units

From Bridgerton (Netflix) to Sanditon (ITV), there is a current boom in Regency adaptations that practice "colorblind" or "color-conscious" casting while interrogating the period's gendered and racial dynamics. But how were race and gender, and their intersections, actually forged and navigated in the age of Austen? This 300-level course will look at Romantic-era in both a historical and a contemporary context. Through reading, viewing, and graded assignments including short essays and oral presentations, we will practice methods for analyzing the formal features of literary and visual texts, such as the structure of a novel, the rhythms of poetry, or the costuming of period drama. In doing so, we will ask: how do these texts respond to historical phenomena such as empire, the rights of women, and slavery and abolition? How and why do contemporary adaptations take up these questions? Examples of readings include Aphra Behn's Ooronoko, Jonathan Swift's "The Lady's Dressing Room," Jane Austen's Mansfield Park, Mary Prince's The History of Mary Prince, and William Wordsworth's "To Toussaint L'Ouverture."

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-342 Love: A Cultural History

Spring: 9 units

This is a course about the cultural history of love. We will focus on romantic love, with an emphasis on how ideas about love have been a dynamic part of our social, political and economic world. Some of the questions to be addressed include: How, historically, did the idea of love become coupled with freedom? How did romantic love come to be considered the epitome of self-fulfillment and what are the problems with that idea? How has the idea of romantic love been mobilized on behalf of things like the state, the nation, capitalism or revolution? How do types of love function as a measure of belonging or deviance? How does the discourse of love enter different kinds of institutional arrangements, such as marriage or state citizenship? As a way to explore these questions, this course looks primarily to literature, including fiction, poetry, and drama, but also to philosophy, history, anthropology, sociology and law. Students will immerse themselves in an interdisciplinary range of material as they read, discuss and write about these representations. We will roam through cultural theory of affect, psychoanalytic notions of love, historical constructions of marriage, and feminist discussions of love and sexuality. The emphasis will be on Euro-American narrative traditions, but the final part of the course will include a contemporary global comparative context.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-343 Rise of the American Novel

Intermittent: 9 units

This course will survey American fiction from the beginning of the nation through the first half of the twentieth century. We will look at early fiction, like Washington Irving's "Rip Van Winkle" and mid-1800s classics like Hawthorne's *Scarlet Letter*, up to twentieth-century works like *The Great Gatsby* and perhaps some contemporary novels. Through the term, we will ask how the fiction represents the special character of American experience. Alongside readings, you will write several short papers and present some of your research to the class.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-347 Recent American Fiction

Intermittent: 9 units

We will read very recent American fiction, from about 1990 to the present. Authors would include Chimamanda Adichie, Michael Chabon, Junot Diaz, Jennifer Egan, Bret Easton Ellis, Jonathan Lethem, and Colson Whitehead. We will try to gather trends or tendencies that distinguish it from previous fiction. Does it suggest a different moment in fiction from postmodernism? And does it have a comment about American culture and its relation to the contemporary world?

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-108 and 76-106)

76-349 Climate Fictions

Intermittent: 9 units

During the last 20 or so years, a new kind of fiction has emerged responding to scientific models of climate change. Climate fiction, or "cli-fi," most often imagines a future in which nothing has been done or done soon enough to limit global warming. Much of this literature fits into the broad genre of science fiction, but some of it uses other fictional modes, including realism and postmodernism. This course will look at a variety of fictional approaches to climate change, including a few in visual media. We will consider why fiction is a necessary component of our understanding climate change: computer models are fictions of a sort but also whether and how fictional narratives such as novels and films can help motivate action. We may also read some earlier narratives of environmental catastrophe, and some nonfictional discussions of climate change. Likely authors include Amitav Ghosh, Margaret Atwood, Barbara Kingsolver, Kim Stanley Robinson, and Richard Powers.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-350 Critical Theories about Literature

Intermittent: 9 units

This course studies the long-debated problem of how readers or spectators respond to texts (in print, performances, film, or painting) from ancient rhetoric and tragedy to contemporary mass culture. We will read in a range of critical theories, from thinkers like Aristotle, Plato, and Longinus to recent theorists in poststructuralism, gender studies, Marxism, and affect theory. How have such critics and theorists thought about the nature of the text and of representation and #8212; or the relation of authorship to reading, ideas, and affects? What techniques of analyzing literary texts have such theories stimulated? Two papers and vigorous in-class discussion will be required.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-351 Rhetorical Invention

Intermittent: 9 units

Rhetorical invention is a discursive approach to the process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use in any situation. In other words, it is a rhetorical approach to content generation in any speaking or writing situation. Although invention is centrally important to rhetoric without it rhetoric becomes a superficial and marginalized study of style and arrangement from the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study, influenced by the view that the content of communication should be exclusively governed by deductive logic and the scientific method rather than rhetorical considerations such as audience, situation, or the history and figurality of language. This repudiation of rhetorical invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we examine the status of rhetorical invention in the development of modern thought and then attend to scholarly efforts to revive a rhetorical understanding of invention from the mid-twentieth century forward, surveying contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings. In addition to regular reading responses, students select a research project examining the history or theory of rhetorical invention.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-352 Music, Technology, and Culture

Intermittent: 9 units

Music has been a part of our individual and communal lives for 40,000 years. We developed the technology to record and playback music for about 140-years ago. In this seminar we will study the relationship of music, technology and culture from a variety of disciplinary approaches including science and technology studies, musicology and ethnomusicology, neuroscience, sound studies, Black studies, political economy, cultural studies and media archeology. The course will focus on the impact mediating technologies like vinyl, cassette tapes, mp3s, film and television, the development of music journalism and of course live human performance have had on our social, political and personal interactions with music. We have built the course around case studies that illustrate the intersection of music, technology and culture such as audio analgesia devices, movie soundtracks, streaming services, the rise of internet "listicles" and other crucial moments in twentieth and twenty-first century musical culture. Students in this course will develop critical projects that cross technological, humanistic, and musical boundaries. We hope that students come away from this class with better a host of critical tools to better think about what music means to us and how mediating technologies redefine these meanings.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-353 Transnational Feminisms: Fiction and Film

Intermittent: 9 units

How do controversial practices related to women become touchstones that draw women together across cultures or, conversely, push them into separate cultural and political spheres? This introductory-level course familiarizes students with the challenges transnational feminism has posed to Western notions of feminism. To explore these contestations, we will look at a series of controversies. We will read these controversies through novels, drama, short stories and films, with some secondary theoretical readings. This course will take six case studies concerning cultural practices that have generated global debates about the status of women and issues like consent, freedom, and equality. Beginning with several works about regional/Islamic practices of veiling, we will look specifically at the close connections made between women's practices and elements of tradition, including religion. With an eye toward historicizing feminist interventions, we will look at 19th century debates on sati, commonly called widow burning, in India, to see how certain issues became loci for global intervention during colonial periods and, later, for global feminist movements. Within the contemporary period, we will turn to cultural, economic and political practices like female genital cutting, transnational domestic labor, global sex trade, and transnational forced marriage. For each of these controversies, we will be reading a range of positions represented in different types of writing across genre, with a focus on literary and filmic depictions.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-354 Watchdog Journalism

Intermittent: 9 units

The practice of journalism involves covering the news of the day. Investigative journalism uncovers it, digging through public records and data to expose corruption or correct social injustices. The process takes patience and persistence, as well as familiarity with right-to-know laws, to find that gold nugget of information that exposes secrets or becomes the missing piece to a larger puzzle. In this course, students will learn investigative techniques that make the powerful accountable, using government documents, financial filings and databases to spot undetected crime patterns, an unfair housing policy or perhaps questionable spending by a non-profit charity. Investigative journalism has a storied history of exposing wrongdoing and today many of the tools historically used to tell those stories are available to everyone. This course will help budding journalists, researchers and anyone else interested in addressing societal problems find those tools and learn how to use them. This course meets the Dietrich College Deciding Gen Ed requirement.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-355 Leadership, Dialogue, and Change

Fall: 9 units

This course offers an alternative to the "great man" theory of leadership and #8212;in which success is built on charisma, power, status, or institutional authority. The contemporary model of "adaptive leadership," however, depends on an ability to draw a divided community into a dialogue that re-frames the problem and may even call on us to re-interpret our values. We will see this in action, comparing the methods of Martin Luther King to the radical community organizing of Saul Alinsky, and in the influential of African-American cultural critiques of Cornel West and bell hooks, and in the work of students calling for change on campuses. All this work poses a question: how does dialogue work in the rhetoric of making a difference? So in the second half, we put theory into practice, organizing a CMU Community Think Tank on a campus issue, in this case on student empowerment will learn strategies for analyzing a problem, framing, issues, giving rhetorical presence to those problems and creating counterpublics that put new ideas into circulation. The class collects data across diverse, often competing perspectives, to create a Briefing Book, that will guide your live Round Table problem-solving dialogues, and then document, write and publish your Findings www.cmu.edu/thinktank. As a portfolio project it will demonstrate your ability to support problem-solving dialogues across difference in a community or organization.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-357 Linguistic & Social Aspects of Immigration

Intermittent: 9 units

This course introduces students to the linguistic and social aspects of immigration in today's global society. Immigration will be studied as a socio-political construct with an emphasis on the linguistic, socio-cultural, and political challenges and opportunities that migration creates for the individual and society. Throughout the course we will explore one key question: What challenges and opportunities do different aspects of migration possess for multilingual societies and individuals? A great deal of the course focuses on the linguistic challenges that migration creates for the individual and society, with a special emphasis on the development of bilingualism and the education of immigrant children. From a larger socio-political perspective, the course focuses on various case studies of immigrant populations throughout the world in order to obtain a better understanding of the characteristics, opportunities, and challenges faced by immigrant populations internationally.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-359 User Experience Methods for Documents

Intermittent: 9 units

This course will be useful for any student who is interested in learning more about user experience methods that are widely used in professions such as designing/writing for new media, technical writing, science and healthcare communication, public media relations, policy and non-profit communication. You will deepen your mastery of the following research skills associated with planning and testing documents: interviewing in context, retrospective interviewing, focus groups, surveys, and think-aloud usability testing of documents. In addition to specific research methods and skills, we will cover issues that pertain to all research methods: How many people do I need to include in my study? How should I select them? Are my results valid? Is what I think I'm finding out reliable? What are the ethical issues in my study? We will use a combination of lecture, discussion, exercises and projects to achieve these objectives.

Prerequisites: (76-390 and 76-270) or (76-271 and 76-390)

76-360 Literary Journalism Workshop

Intermittent: 9 units

S23: How can storytelling and reading literature help us understand the worlds of healing and illness? We'll read texts focusing on doctors, nurses, patients, caregivers, those living with chronic illness, and disability. Students will write about their own experiences, and those of loved ones. Prerequisites: 76-260 or 76-261 or 76-270 or 76-271 or 76-372 or 76-472 or 76-262 or 76-265

76-361 Corpus Rhetorical Analysis

Intermittent: 9 units

The Digital Humanities is a huge and growing field spanning many disciplines and skill sets. The focus of this course is on tools and methods that allow students to analyze textual corpora as purveyors of stories, information, and arguments that seek to influence cultural thinking, reveal existing cultural mindsets, and often both in tandem, either synchronically or diachronically. This is the point of view often taken by analysts who work for universities, think tanks and intelligence agencies who seek to understand cultural trends and mindsets from volumes of digital texts. For such analysts, close reading is an indispensable part of their work and computing tools help focus their reading while reading helps refine their understanding of the computer output. The course will give students intensive practice with methods and tools for analyzing corpora of text at the word, phrase, and sentence level, and with working with large scalable dictionaries and multivariate statistics.

Prerequisites: (76-108 or 76-106 or 76-102 or 76-101 or 76-107 or 76-106 or 76-107 or 76-108) and 76-380

76-362 Reading in Forms: Nonfiction

Intermittent: 9 units

In this reading-intensive course we will analyze and discuss different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term "creative non-fiction" mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We'll be reading a selection of essays from a variety of writers, as well as full works from a few writers considered masters of the form.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-363 Reading in Forms: Poetry & Prose

Intermittent: 9 units

This course demands intensive reading of contemporary novels, stories, essays, and poetry. We will read works created by writers from wide variety of cultures, including but not limited to Indian, Korean, Palestinian, Brazilian, Irish, and African American. Students will be asked to write in response to readings, and will also produce their own creative work in all three genres.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-364 Reading in Forms: Fiction

Fall and Spring: 9 units

Topic varies by instructor and semester. Fall 2022: What does it mean to live in a family? In this course, we will read and discuss fiction and memoir that centers on the complex experience of living in a family. We'll look at different kinds of families and the way each is shaped by culture, economics, and the psychology of its members. We'll encounter stories of families that bond and those that fray, at families people have been born into, and ones they have chosen in later life. A response papers will be due for each class. Active participation in discussions is a major part of your course work. Students will also be responsible for presenting one of the creative works and a final paper.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-365 Beginning Poetry Workshop

Fall and Spring: 9 units

In this course students will read and discuss the poems and collections of contemporary poets, attend outside readings and events, critique their classmates' poems, and create a body of poetic work. We will look closely at such things as lineation and form, hybrid and multimedia poetics, and the role of poetry in a charged political and pandemic landscape. I will encourage students to experiment and to take their craft in new directions through weekly writing assignments and in-class exercises. Ultimately, this course will help students become stronger writers, readers, and critics.

Prerequisites: (76-102 or 76-107 or 76-106 or 76-101 or 76-108) and 76-265 Min. grade B

76-366 Essay Writing Workshop

Intermittent: 9 units

In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term creative non-fiction mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We will scrutinize the writing of Eula Bliss, Kate Fagan, Joan Didion, James Baldwin, Jo An Bear, Gary Younge, David Foster Wallace, Umberto Eco, and many others. In addition to critical writing assignments, students will have several opportunities to write their own non-fiction pieces.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-367 Fact Into Film: Translating History into Cinema

Intermittent: 9 units

From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as *The Fall of the Roman Empire*, *The Gunfight at the O.K. Corral*, *Saving Private Ryan*, *World Trade Center*, *Enemy at the Gates*, *Lagaan* and *Hero*.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-368 Role Playing Game Writing Workshop

Fall: 12 units

Role playing games (RPGs) are a vibrant and viable popular medium for interactive storytelling. This workshop builds upon dramatic theory DNA existing in plays, TV and film. Gameplay is performance. The skills developed when creating any time-bound media transfer well to games but must be seen through a different lens - the lens of the player. To do so, we first examine and dissect both RPG story and game design (using pencil and paper examples) seeking an understanding of both game systems as well as narrative best practices. In class we focus our examination on the most popular existing intellectual property (*The Lord of the Rings*). Students who desire admittance to this class should be at least somewhat familiar with that world to succeed in the class. Each student works on a four-person team to create an original RPG campaign-style adventure for an already existing story world. The final product is a portfolio-quality set of dramatic scenes, epic tabletop encounters, and character sketches. This is not an RPG design course. Any level of writing experience is welcome, BUT experience playing RPGs and #8212; either tabletop or video game and #8212; is a must. Experience as a GM for an RPG is a big plus, and applicants who possess such experience should be sure to let the instructor know in advance.

Prerequisites: 76-269 Min. grade C or 76-260 Min. grade C

76-370 Independent Study in Literary and Cultural Studies

All Semesters

An Independent Study course is a course taken with faculty supervision that goes beyond the courses offered in a particular area of interest. It should not duplicate a course offered in the regular schedule of classes. A student wishing to take an independent study needs to locate a faculty member whose research interests are close to the area of proposed study and meet with the faculty member to discuss whether it is something the faculty member is interested in doing. The department requires that the student and instructor submit a written contract (available in the English Department) detailing the expectations (description of course of study, readings, how often the student/faculty member will meet) and requirements for the completed independent study project (number and amp; length of papers) and a time-line for completion of the work. You should think of this as developing the equivalent of a detailed course syllabus/schedule, and typically involves development of a bibliography of readings.

76-371 Teamwork for Innovators

Intermittent: 9 units

Academic teams, campus organizations, workplaces are all dynamic activity systems, organized and driven by institutional habits and rules, by roles, status and power, and by the material and conceptual tools we draw on. Yet as we have all observed, these Rules, Roles and Tools often operate in contradictory ways, even in conflict with one another. Effective team leaders are able to recognize these contradictions and draw a writing group, a project team, a social organization or a workplace into what is called an "expansive transformation." That is, to innovate new ways of working together. In this course, you will learn how to become more effective not only as a team member, but also a project leader, and even group consultant in your college work and workplace. Looking at films, case studies, research, and your own experience, we will learn how to analyze how teams of all sorts are working, to communicate more effectively across different expectations and values, and to collaboratively innovate new ways of working together. Your final project will let you document your ability to be a knowledgeable team leader and effective collaborator.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107)

76-372 News Writing

Fall: 9 units

In this course, we will study and learn the fundamental skills of journalistic writing as well as discuss topics related to how different media outlets cover news. On the writing side, we will start with the basics - the importance of accuracy, clarity and fairness, writing for audience, striving for objectivity, judging newsworthiness, meeting deadlines. The core class work (and most of your grade) will be based on seven writing assignments due approximately every two weeks throughout the semester. Expect to do some writing each class period. We will learn how to write a story lead, how to structure a story and how to write different kinds of news stories, from crime news to features to editorials and commentary. We also will learn how to research a news story, conduct an interview and sort through mountains of information to discern what's important so we can write about it in a clear, concise manner.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-373 Argument

Fall and Spring: 9 units

This course introduces the fundamentals of argumentation theory and offers guided practice in analyzing and producing arguments. Through analysis, we will learn what an argument is, how to identify one, and what the names and functions of a variety of argument features are. We will also explore the production of argument by pursuing the questions: What are my argumentative goals? How do I build a theory of my audience? What means of persuasion are available for me to achieve my goals? And how should I order the contents of my argument? To answer these questions, we will explore argument in a variety of genres including visuals, op-eds, presidential speeches, and congressional testimonies.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-374 Mediated Narrative

Spring: 9 units

This course is structured as a project-based class where students will explore the properties of non-linear, multi-linear, and interactive forms of narratives and apply them to create a computer-based media project about the future of humankind in the year 2073. Students will be encouraged to think critically considering broader issues of analytical representation such as environment, sustainability, communication, culture, economy, labor, politics, social order, architecture, transportation, biology, etc. Students will work in the areas of research, creative writing, video production, interactive media, data visualization and programming. Based on all the evidence and existential variables investigated during the class students will have to create their own version of the future in the year 2073 and #8212;Fifty years from now.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-375 Magazine Writing

Intermittent: 9 units

In this course we'll be reading lots of great nonfiction, some of which has appeared in magazines during the past few years. We'll look at how excellent nonfiction for magazines has to employ a strong narrative voice, and the techniques of storytelling. Students will be asked to research and write their own articles, based on a variety of assignments. The class will be conducted as a discussion, and demands participation from each class member.

Prerequisites: 76-260 or 76-262 or 76-372 or 76-272 or 76-271 or 76-270

76-377 Shakespeare on Film

Intermittent: 9 units

The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied corpus of films that includes legendary performances, adaptations from across the full breadth of world cinema, and experiments in every major genre. This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of authorship, adaptation, technology, and performance. As we watch, read, write, and converse together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context and how film has helped to shape Shakespeare's unparalleled cultural influence. Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-378 Literacy: Educational Theory and Community Practice

Spring: 9 units

Literacy has been called the engine of economic development, the road to social advancement, and the prerequisite for critical abstract thought. But is it? And what should count as literacy: using the discourse of an educated elite or laying down a rap? This course combines theory, debate, and hands-on community engagement. Competing theories of what counts as "literacy" and how to teach it shape educational policy and workplace training. However, they may ignore some remarkable ways literacy is also used by people in non-elite communities to speak and act for themselves. In this introduction to the interdisciplinary study of literacy's history, theory, and problems we will first explore competing theories of what literacy allows you to do, how people learn to carry off different literate practices, and what schools should teach. Then we will turn ideas into action in a hands-on, community literacy project, helping urban students use writing to take literate action for themselves. As mentors, we meet on campus for 8 weeks with teenagers from Pittsburgh's inner city neighborhoods who are working on the challenging transition from school to work. They earn the opportunity to come to CMU as part of Start On Success (SOS), an innovative internship that helps urban teenagers with hidden learning disabilities negotiate the new demands of work or college. We mentor them through Decision Makers (a CMU computer-supported learning project that uses writing as a tool for reflective decision making.) As your SOS Scholar creates a personal Decision Maker's Journey Book and learns new strategies for writing, planning and decision making, you will support literacy in action and develop your own skills in intercultural collaboration and inquiry. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-380 Methods in Humanities Analytics

Spring: 9 units

The computer-aided analysis of text has become increasingly important to a variety of fields and the humanities is no exception, whether in the form of corpus linguistics, stylometrics, "distant reading," or the digital humanities. In this course, we will build a methodological toolkit for computer-aided textual analysis. That toolkit will include methods for the collection data, its processing via off-the-shelf software and some simple code, as well as its analysis using a variety of statistical techniques. In doing so, the class offers students in the humanities the opportunity to put their expertise in qualitative analysis into conversation with more quantitative approaches, and those from more technically-oriented fields the opportunity to gain experience with the possibilities and pitfalls of working with language. The first part of the term will be devoted to introducing fundamental concepts and taking a bird's eye view of their potential application in domains like academic writing, technical communication, and social media. From there, students will initiate projects of their own choosing and develop them over the course of the semester. The goal is to acquaint students with the strengths and limitations of computer-aided textual analysis and to provide them with the necessary foundational skills to design projects, to apply appropriate quantitative methods, and to report their results clearly and ethically to a variety of audiences. This class requires neither an advanced knowledge of statistics nor any previous coding experience, just a curiosity about language and the ways in which identifying patterns in language can help us solve problems and understand our world. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-384 Race, Nation, and the Enemy

Intermittent: 9 units

Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-385 Introduction to Discourse Analysis

Intermittent: 9 units

"Discourse" is language: people talking or signing or writing. Discourse analysts ask and answer a variety of questions about how and why people do the things they do with language. We study the structure of written texts the semi-conscious rules people use to organize paragraphs, for example as well as the unconscious rules that organize oral discourse such as spontaneous stories and arguments. We study how people signal their intended audience-interpretations of what they say as foreground or background information, a casual remark or solemn promise, more of the same or change of topic. We look at how grammar is influenced by what people need to do with language, and how discourse affects grammar over time. We ask how children and other language learners learn how to make things happen with talk and writing. We ask how people learn what language is for, from exchanging information to writing poetry to perpetuating systems of belief. We analyze the choices speakers and writers make that show how they see themselves and how they relate to others. (Choices about how to address other people, for example, both create and reflect relationships of power and solidarity). We study how people define social processes like disease, aging, and disability as they talk about them, and how language is used to mirror and establish social relations in institutional settings like law courts and schools as well as in families and among friends. This course touches on a selection of these topics and gives students practice in analyzing the complex nuances of language. The course is meant for anyone whose future work is likely to involve critical and/or productive work with language: writers and other communication designers, critics who work with written or spoken texts, historians, actors, sociologists, and so on. Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-108 and 76-106)

76-386 Language & Culture

Intermittent: 9 units

This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose. Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-387 Writing in the Disciplines

Intermittent: 6 units

This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-108 and 76-106)

76-388 Coding for Humanists

Intermittent: 9 units

This course provides students with the foundational knowledge and skills to develop and/or utilize computer-aided research tools for text analysis. Through a series of hands-on coding exercises, students will explore computation as a means to engage in new questions and expand their thinking about textual artifacts. This course is designed for students with no, or very little, coding experience. So, if you have already taken a programming course, this course is most likely not for you. Students who have taken 15-110 and/or 15-112 may not take this course. For the final project, you will develop a small research project involving a computational analysis of a corpus of texts. You will plan, design, and write a computer program that processes and analyzes a textual corpus of your choice. Students who are taking the course for 9-unit will write a brief project report (3-5 pages) that summarizes your final project. Graduate students in the MA in Rhetoric/PhD programs must register for 12-unit, and will complete a research paper (4,000-5,000 word).

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-389 Rhetorical Grammar

Fall and Spring: 9 units

This is a course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-390 Style

Fall and Spring: 9 units

This course teaches you how to write clearly. Specifically, the principles you learn in this course will help you 1) to clearly represent actions and the characters responsible for them; 2) to make your paragraphs coherent and cohesive; 3) to write sentences that stress important information; 4) to cut unnecessary prose; and 5) to reshape lengthy sentences so as not to perplex your reader.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-107) or (76-106 and 76-108)

76-391 Document & Information Design

Fall: 9 units

This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects.

Prerequisites: 76-270 or 76-271

76-392 Special Topics in Literature & Culture

Intermittent: 9 units

Topics vary by semester. Fall 2022: The American Novel - This course will survey the history of American fiction. We will look at novels and short stories in three broad periods: from the early 19th century to the Civil War (Poe, Melville, and Hawthorne); from the late 19th century (Howells, James, and Jewett); and from the early 20th century (Hemingway, Stein, and Le Sueur). While we will try to cover well-known figures, we will also look at some lesser-known ones, such as Rebecca Harding Davis, who wrote about factory life in the 1850s, and George Schuyler, who wrote science fiction in the 1930s. Typically, American fiction is said to move from Romance to realism to modernism to postmodernism. One of our tasks is to consider what these mean and how they apply. In addition, we will consider some of the cultural, social, and institutional conditions that create fiction. How does fiction respond to shifts in printing and book production? to industrialization after the Civil War? How do ideas of gender and race shape the fiction? Alongside our readings, you will also have three papers and presentations drawing on them to build our archive of what we know about this fiction.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-393 Narrative & Argument

Intermittent: 9 units

This is course for non-English majors interested in understanding and practicing writing as an art of design thinking and decision-making. We work through seven writing exercises divided into "experiential" and "informational" clusters and we discuss the underlying design principles that unite and divide these clusters. Experiential writing (think character-based fiction, personal profiles, travel writing, narrative histories) supports reader learning but in an indirect, unsupervised fashion. Students write short papers within each of these clusters to glimpse and grapple with the different compositional (design) challenges. Within experiential writing, students practice making themselves (from the first person) and third parties characters readers can come to know and care about. They practice immersing readers within immediate and historical scenes by creating the feel of extended space or elapsed time. Within information writing, students practice presenting readers with new ideas by following the readers' native curiosity (exposition), guiding readers through manual tasks (instruction), and structuring readers' decision-making (argument) in controversies when there are multiple decision paths. Argument is a capstone of information writing that bids for social and political change. While writing for experience and writing for information are distinct clusters, they are highly interactive and the best information writers routinely import techniques of experiential writing into their craft to enliven and layer the reader's experience.

Technologies for making visible for students their tacit decision-making over hundreds and thousands of compositional moves when writing experience and information are introduced and provide students a literal "lens" on the texts they write as an endlessly curious design artifact.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-107 and 76-108) or (76-106 and 76-108)

76-395 Science Writing

Spring: 9 units

You will learn how to write clear, well-organized, compelling articles about science, technology and health topics for a general audience. You will learn how to carry out research on scientific topics using primary and secondary sources, how to conduct interviews, and how to organize that information in a logical fashion for presentation. For writing majors, the course will increase their understanding of scientific research and how to describe it accurately and in a compelling manner to a general audience. For science majors, this course will teach them how to craft fluid, powerful prose so that they can bring their disciplines to life. The course is not intended just for those who want to become science writers, but for anyone who may have the need to explain science, medicine, or technology to a general audience, whether it is an engineer describing a green building project at a public hearing or a computer programmer describing new software to a firm's marketing staff. Scientists and educators today are increasingly concerned about the public's lack of understanding about scientific principles and practices, and this course is one step toward remedying that deficit. You will get a chance to read several examples of high-quality science writing and interview researchers, but the primary emphasis will be on writing a series of articles, and rewriting them after they've been edited. Your assignments will range from profiles of scientists to explanations of how something works. In particular, this year's class will focus on how science and society interact, whether that means the way that science writers write about public health and the COVID pandemic or climate change. The class will be run partly as a writing workshop where students will be organized in teams where they will discuss ideas, as well as edit and critique each other's work in class, in a process similar to what journalists routinely go through.

Prerequisites: (76-102 or 76-101 or 76-106 or 76-108 or 76-107) and (76-270 or 76-472 or 76-375 or 76-372 or 76-271)

76-396 Non-Profit Message Creation

Intermittent: 9 units

Non-profit organizations support a multitude of causes ranging from the arts to animals to the environment to health care to human rights to scientific research to many great causes in between. Non-profits achieve their missions by advocating on behalf of their organization's cause, raising public awareness about issues surrounding their cause, and fundraising to make their advocacy possible. In this course, students will select a local, Pittsburgh-area non-profit to examine and produce materials based on the organization's needs. Over the course of the semester students will research the organization's persona and values via interviews with chosen organization's staff and analysis of existing communication channels and different forms of content currently used by the organization. Students will use this research and analyses to inform and shape a final project that should meet the specified, needed deliverables from the selected non-profit. Previous example projects include: Revising a newsletter and specifying future best practices for an organization; developing new format and copy for an organization's website; developing a social media campaign for an upcoming event; developing a grant proposal for an organization's project; among many others. Students will have a wide selection of organizations to choose from and know projects associated with the organization at the beginning of the semester, as these will be organized by the professor. At the end of the course, students will have a portfolio ready material and an increased understanding as to how non-profit organizations advance their causes.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-397 Instructional Text Design

Intermittent: 9 units

This course focuses on the planning, writing, and evaluating of instruction of various kinds, especially instructional texts. It is particularly appropriate for professional and technical writers, but also a good option for anyone interested in fields that involve substantial instruction, such as teaching or employee training. In the first part of the course, we'll examine the recent history of instructional design and the major current theories. Then we'll take a step back and study the concepts of learning upon which these theories are based, with particular attention to their implications for how instruction is structured. You'll find that different learners (e.g., children, older adults) and goals (e.g., learning concepts and principles, learning to apply principles to solve novel problems, learning a procedure, learning to change one's behavior, etc.) require different types of instruction. In the second part of the course, we'll look in detail at models of how people learn from texts and what features (e.g., advanced organizers, examples, metaphors, illustrations, multimedia) enhance learning under what circumstances. We will study and analyze particular types of texts. Some possible examples include an introduction to the concept of gravity; a tutorial for computer software; a self-paced unit in French; adult educational materials in health care; a workshop on sexual harassment in the workplace; or a unit to train someone how to moderate a discussion. We will also look at various methods (concept mapping, think-aloud, comprehension tests, etc.) that are used to plan and evaluate instructional text. You will do a project, either individually or in a small group (2-3), in which you design, write and evaluate instruction.

Prerequisites: 76-270 or 76-271

76-401 Hollywood vs. the World

Intermittent: 9 units

For almost a century the American film industry has dominated popular media worldwide. Anywhere in the world, American stars, American films, and American modes of storytelling are never far away. Why and how was that dominance achieved, and how have other cultures and industries challenged it? Film and television account for billions of dollars of U.S. exports and provide one of the key sources of global "soft power" and cultural influence. Understanding how that dominance works is therefore crucial to the question of America's economic, political and cultural place in the world. This course will examine ways in which other national cinemas have fought, or are currently fighting, against the hegemony of American popular film culture, and the ways in which the American film industry has maintained its dominant position in world markets for nearly a century.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-403 The Crucible of Modernity:Vienna 1900

Intermittent: 9 units

Vienna at the turn of the century (that is, at the turn of the last century, 1900) was many things: the political center of the Habsburg dynasty of the Austro-Hungarian Empire; the meeting place of Czechs, Slovaks, Hungarians, Romanians, Slavs, Poles, Italians, Serbs, Bulgarians, and Germans; the center of German-language music and theater; the birthplace of Zionism and of psychoanalysis; the battleground for liberalism and anti-Semitism; a haven for socialism; the home of caf and #233;-culture and the waltz; the garrison for an outdated army; the city of baroque urban palaces and squalid backyard tenements; the center for Enlightenment public policy and reactionary bureaucracy; and the showcase for historicism. And while the story of Viennas cultural and political turmoil is interesting, it probably would not command our attention today were it not for its role as the birthplace of Modernism. In an effort to understand todays intellectual environment, therefore, we will examine Vienna before the collapse of the Austro-Hungarian Empire in 1918. We will be looking at a huge and at times confusing canvas which by necessity includes almost every aspect of culture. We will start with politics and history and move on through art, architecture, crafts, psychoanalysis, literature, music, and philosophy. We will be looking at art nouveau buildings and furniture, reading literature, viewing films, and listening to recordings - and we will build 3D models on a digital map which will help us understand how the different arts were all connected and influenced each other. Language of instruction: English

76-404 Critical Race & Ethnicity Studies

Intermittent: 4.5 units

Terms commonly associated with the academic study of race and ethnicity have gained or regained prominence within our always volatile political discourse: intersectionality, identity politics, white supremacy and blackness. But what is critical race and ethnic studies? What are the "theories" about race, ethnicity, art, subjectivity, power, knowledge and the human that have driven the scholarship and intellectual work for scholars committed to an interdisciplinary exploration of race and ethnicity? This course will introduce students to some of the key figures, terms, debates that have emerged out of critical race and ethnicity studies with a particular focus on how the "structuralist controversy", which foregrounded critiques of the "subject" have changed the way scholars talk about race, ethnicity and identity since the middle of the twentieth-century. Given the wide ranging and interdisciplinary nature of critical race and ethnicity studies our readings will inherently cover disciplines such as literary criticism and theory, legal studies, anthropology, linguistics, science and technology studies and film studies to name a few. Readings may include: W.E.B. Du Bois, Kimberly Crenshaw, bell hooks, Richard Dyer, Edward Said, Stuart Hall, Michel Foucault, Jacques Derrida, Henry Louis Gates Jr., Claudia Sharpe, Denise D' Silva, Gayatri Spivak, Eduardo Bonilla Silva and Achille Mbembe. There will be two short papers.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-405 Institutional Studies: English as a Discipline

Intermittent: 4.5 units

The institution on which this course will focus is the academic discipline, the specific historical form that the production of knowledge in the modern research university has assumed. This course will examine the historical development of the discourses, practices, organs, and associations that have defined English as a discipline. While we will of necessity also look at the theories and values that the discipline has proclaimed at different times, this will not mainly be a course in the history of criticism. Criticism will be considered as one practice among others including philology, literary history, literary theory, rhetoric, and composition. In order to understand the broader context, we will read work by Foucault and others on disciplinarity. We will also examine allied institutions, including the professions and the university.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-406 Introduction to Black Studies

Intermittent: 9 units

This seminar will take an interdisciplinary, historical and transnational approach to the field of Black Studies. We will focus on key figures, events, debates, terms, books, essays, and anthologies that anticipate as well as constitute the emergence of Black Studies as a discipline in the wake of Black student protests in the 1960s. Since this seminar is being offered in an English Department, we will spend a significant part of our seminar discussing the political, methodological and institutional impact of Black Studies on English Departments after 1968. In particular we will explore the fraught relationship between Black Studies and African-American Studies as well as investigate the intertwined institutional history of these two fields throughout the late twentieth and into the twenty-first century. We will undoubtedly read and read about figures like W.E.B Du Bois, Sylvia Wynter, Franz Fanon, C.L.R. James, Angela Davis, Molefi Kete Asante and Saidiya Hartman to name a few.

Prerequisites: 76-101 or 76-102 or (76-108 and 76-106) or (76-107 and 76-106) or (76-107 and 76-108)

76-407 Topics in Literary & Cultural Studies

Intermittent: 9 units

Topics vary by semester. Spring 2022: There Are Black People in the Future. In 2018 the African American artist and CMU professor, Alisha Wormsley created a slogan for a billboard in Pittsburgh's East Liberty that read: THERE ARE BLACK PEOPLE IN THE FUTURE. The billboard had featured many artists and slogans over a period of years, but this one was taken down when the building's landlord objected to the content. The controversy over this piece of art gives this course its name. There are black people in the future, and there are extraordinary black artists in Pittsburgh at this very moment. This special topics course will consider what some are calling a new Pittsburgh Renaissance in the black arts, from art to literature to film and music. Featured writers include Deesha Philyaw, *The Secret Life of Church Ladies*, Brian Broome, *Punch Me Up To The Gods*, and Damon Young, *What Doesn't Kill You Makes You Blacker*. We will also look at the work of the writer Jason England, the artists Alisha Wormsley, Vanessa German, Devan Shimoyama, the rapper Jasiri X, and the film maker Chris Ivey. An in depth look at these artists will be paired with an examination of the history of African Americans in Pittsburgh, and current economics, sociology and politics surrounding race in the city.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-408 Culture and Globalization

Intermittent: 9 units

We are often told we live in a period of globalization, but what that means differs widely. Theories of globalization describe such diverse processes as international capital and markets, neo-liberalism and neo-colonialism, environmental devastation, transnational labor and migration, modernity, shifts in spatial and temporal relations, cosmopolitanism, global cultural production and consumption, and the resurgence of nationalism. In this course we will explore and historicize the concept of globalization from both a global literary perspective and an interdisciplinary lens. Pairing literary works from around the world with scholarship from sociology, political science, gender and critical race studies, and anthropology, we will examine the contradictions, conflicts and possibilities of associated changes in the world. We will investigate the role of representation and aesthetics by considering the work of literary writers as well as some filmmakers, journalists and activists. The course will be organized as a series of topical foci that might include neoliberalism and labor, the local and the global, environmental changes, secularism and tradition, the globalization of feminism, and global migration and border control.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-410 The Long Eighteenth Century

Intermittent: 9 units

Angela Davis wrote that "freedom is a constant struggle": how do the freedom struggles of the long eighteenth century continue into the present? How were "modern" categories of race and gender forged and navigated in the long eighteenth century? In this course, we will study literature and culture between roughly 1660 and 1820, an era in which historical phenomena such as European empires, the Rights of Woman, and slavery and abolition coincided with changes in print and media culture to produce profound cultural changes that are still with us. Through reading, discussion, and graded assignments including short essays and oral presentations, we will examine the interanimating relationship of literature and history in moments of crisis. Examples of primary readings include Aphra Behn's *Ooronoko*, selections from Milton's *Paradise Lost*, Jane Austen's *Mansfield Park*, Mary Prince's *The History of Mary Prince*, and William Wordsworth's "To Toussaint L'Ouverture." Secondary readings will draw from a variety of critical traditions such as post- and de-colonial studies, Black studies, post-structuralism, and material culture studies.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-412 Performance and 18th Century Theatrical Culture

Intermittent: 9 units

This course has the dual purpose of introducing students to performance and celebrity studies and giving them experience in using these analytic frameworks to study 18th-century literature and culture. Celebrity is a very modern phenomenon that first became a visible part of political, religious, and artistic culture over the course of the long 18th century, between 1660 and 1800. We will investigate the genealogies of modern celebrity, considering such questions as, what do the Kardashians have to do with dead English kings? What can cross-dressing actresses teach us about 21st-century drag performances? (Full disclosure: Dead English kings and cross-dressing actresses will get far more of our attention than the Kardashians or modern drag artists.) We will study some of the most powerful recent theories of performance and celebrity; we will read plays and other performance genres that took up time and space on the 18th-century stage. In addition, we will explore beyond the London theaters to consider the nature of performance in its many cultural forms: What are the connections between theater and the quieter performances of political pamphlets, newspapers, and novels as they occupy physical and mental space in coffee houses and libraries? Can a print text be performative? Finally, we will examine various relationships between performance and culture. How does performance in the early modern period shape gender and sexuality as well as class and race relations? This course will count as an upper-level course for the Gender Studies Minor, as well as a pre-1900 period course for the EBA.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-413 Book Design: A Cultural History

Intermittent: 9 units

Today the book is thriving despite earlier predictions of its "death" at the hands of the digital media. What has made the book so powerful a medium over six centuries? This course will take you into the book's makeup, design, and impact over time. We study how the book was made at different times in its history for instance, the manuscript book (medieval), the hand-press book (Renaissance and eighteenth century), the machine-made book (1800s to present). We also ask how today's databases like Google Books make us see new dimensions of the print medium that were not visible earlier. Likewise we will study theories of the print medium and the cultural effects of the book among readers and social groups. Students will have hands-on experience with a printing press and the Rare Book archives at Hunt and Hillman libraries. Two papers and shorter assignments will be required. Please note: first-year students are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-414 Politics, Media, and Romantic Literature 1789-1830

Intermittent: 9 units

The Romantic period in Britain was a volatile era of political and literary revolutions - but also of print-media revolutions that transformed reading, writing, and publishing. This course focuses the question of books, periodicals, and reading audiences through case studies of several Romantic writers: Mary Robinson, William Blake, Samuel Taylor Coleridge, John Keats, William Hazlitt, and William Wordsworth. Reading a selection of their poems, essays, and critical theory in the context of contemporary debates, we will aim to understand the relation between print as a set of material forms, and political as well as literary ideas and discourses that contended for attention in the period's innovative print media. We will also try to grasp some wider cultural processes at work in the late eighteenth and early nineteenth century. These included disintegration of the early modern Republic of Letters and the reconfiguration of its knowledges in the nineteenth-century cultural fields; the forming and division of new reading publics and their ways of reading print; important changes in book production, typography, printing methods (hand-press to steam press), and bookselling; and the crucially important relation between the aesthetic powers of the "text" and the material pleasures of the "book." Research papers using rare-book materials at the Hunt or Hillman library Special Collections will be especially encouraged; and the course will sometimes meet in the archive to examine "rare and curious" modes of print. One short paper and one research paper will be required.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-415 Mediated Power and Propaganda

Intermittent: 9 units

For most of us, the word "propaganda" triggers a familiar script. We tend to think of totalitarian regimes where the State controls information and prohibits the expression of dissenting views. We also tend to associate propaganda with certain rhetorical techniques - highly emotional words, deceptive representations, and glittering generalities that inhibit rational thought and manipulate public opinion. According to such popular views, propaganda is linked to the dissemination of false information and is antithetical to the norms of democratic society. Our class will challenge these assumptions. First, instead of confining propaganda to authoritarian governments, we will examine how propaganda functions within democratic society. Indeed, we will focus on domestic propaganda in America, especially political propaganda but also propaganda in advertising and public relations. Next, instead of focusing exclusively on deceptive rhetorical techniques, we will ask a more elemental question: What enables propaganda to circulate? Answering this question will force us to consider the routines and values of corporate media as well as the power relations that give some people special access to channels of mass communication. Certainly, we will also examine propaganda messages themselves, attending to manipulative tactics as well as rhetorical strategies used to induce uptake in the mainstream press. We begin our seminar by studying key theories of propaganda, looking at primary texts for various definitions and criticisms of the concept. We will then examine how powerful institutions, especially media organizations, manage the dissemination of propaganda in democracies. Finally, we will consider how to analyze propaganda, generating methodological prerequisites for scholarly study. Ultimately, students will have the opportunity to conduct their own research on propaganda as it relates to their academic and professional goals.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-418 Rhetoric and the Body

Intermittent: 9 units

This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduate students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-419 Media in a Digital Age

Intermittent: 9 units

How are media in a digital age changing? And how are they changing us? What does it mean to be living in today's communication technology "revolution"? In a time when many forms of communication are digitally based, traveling as bits at e-speeds on global computer networks? To begin answering these questions, we will take as case studies several new discursive digital media formations, such as digital books, on-line newspapers, blogs, wikis, and so forth, along with related social formations, such as social media networks and distributed non-profit activist organizations. The readings will provide a range of lens by which to understand these developments, including cognitive, social, political, economic and technological aspects. We will briefly put the development of communication technologies in their historical context: How were new forms of communication received in the past? How were they used? How did they affect communication? How did they influence political and social institutions? We will focus, however, on using knowledge of historical developments to inform our understandings of current digital communication developments. Along the way we will ask questions, such as "What are some of the challenges that new digital formations present to traditional communication theories (e.g., How is trust established when speakers are anonymous and globally distributed? How is the "public sphere" constituted when Internet search engines dynamically construct it?). Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-420 The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process

Spring: 9 units

Ever wondered how a reader is interpreting a text you wrote and how that compares to what you thought it said? Or how does your own process of writing that text compare to the problem-solving strategies experts draw upon? This course explores reading and writing as a social/cognitive process revealing conscious and unconscious problem-solving strategies with which readers comprehend and interpret texts, and writers construct and communicate their meaning. To get at the why behind the surprising things readers do with a text, we will draw on the psychology of reading, where socially constructed memory networks, cognitive schemas, and meta-knowledge actively shape interpretation. To uncover readers' interpretations, we put our knowledge to work trying out user-testing methods that help writers build effective audience-based presentations, applications, websites, or guides. We then take the same approach to writers as thinkers, examining the key problem-solving processes, from task representation, to planning, to revision, on which expert and novice writers often differ. Learning to track problem-solving through process tracing methods, will let you carry out two case studies of your own. The first will uncover the (sometimes radical) differences in how a small set of readers actually interpret a text you find significant. The second will be a case study of your own thinking process on a real task you are doing outside this class. Here you are likely to uncover old unconscious habits, problems you had to solve, as well as unrecognized successful strategies, giving you a new reflective insight into your own thinking as a writer. Freshmen prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-422 Gender and Sexuality Studies

Intermittent: 4.5 units

We will anchor our introduction to this broad and diverse field of theory in the admittedly very limited historical period of feminist, queer, and transgender political activism, circa 1970 to the present day. Instead of attempting "coverage" (an impossible task), we will shuttle between recent work in queer, transgender, and feminist theory and a few key texts that are foundational to the development of academic theory as a reaction to and extension from the political activism of these social movements. Our goals are to strengthen our understanding of the continuities and breaks in politically informed thinking about gender and sexuality, and to deepen our knowledge of the theoretical frameworks available to us from these areas of study. Students will write short response papers to course readings that will help us focus our discussions on their particular interests in literary and cultural studies.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-423 Transnational Feminisms

Intermittent: 9 units

How do controversial practices related to women become touchstones that draw women together across cultures or, conversely, push them into separate cultural and political spheres? This course introduces the challenges transnational feminism has posed to Western notions of feminism. To explore these contestations, we will look at a series of controversies. This course will take six case studies concerning cultural practices that have generated global debates about the status of women and issues like consent, freedom, and equality. Beginning with several works about regional/Islamic practices of veiling, we will look specifically at the close connections made between women's practices and elements of tradition, including religion. With an eye toward historicizing feminist interventions, we will look at 19th century debates on sati, commonly called widow burning, in India, to see how certain issues became loci for global intervention during colonial periods and, later, for global feminist movements. Within the contemporary period, we will turn to cultural, economic and political practices like female genital cutting, transnational domestic labor, global sex trade, and transnational forced marriage. For each of these controversies, we will be reading a range of positions represented in different types of writing across genre, including scholarly writing, legal cases, media debates, films and literature.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-424 Theories of Social Class

Spring: 9 units

How do we define social class? And how do we define popular culture? And what is the relationship between the two? In this class we'll try to answer these questions by looking at the history of class identity in the US, the rise of staggering inequality in the 21st century, and what Newman calls the "labor theory of culture," juxtaposed against the "commodity theory of culture." Texts for the course will include: White Trash: The 400 Year Untold History of Class in America, Robert Reich's documentary Inequality for All, the Oscar winning film Parasite, Netflix's TV series The Maid as well as readings from Marx/Marxist influenced cultural theory.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-425 Rhetoric, Science, and the Public Sphere

Intermittent: 9 units

In the 21st century science and technology are ubiquitous presences in our lives. Sometimes these phenomena spark our imagination and affirm our confidence in a better future. In other instances, they create fear and generate protests over the risks new technologies and scientific ideas pose to prevailing social, cultural, economic, and political orders. In this course we will examine the complex dynamics in the relationships between science, technology, and society. Towards this end we will engage with questions such as: How do we decide who an expert is? To what extent do scientists have an obligation to consider the social and ethical consequences of their work? Is public education about science and technology sufficient for addressing social concerns about risk and controversial scientific ideas? We will grapple with these and other questions by exploring public debates including conflicts over global warming, vaccinations, and the AIDS crisis. With the help of analytical theories from sociology, rhetoric, and public policy, we will develop a framework for thinking about argument and the dynamics of the relationship between science, technology, and the public. We will also look to these fields for tools to assess public debate and to complicate and/or affirm prevailing theories about the relationship between science and society.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-428 Visual Verbal Communication

Fall: 9 units

People create a wide range of communicative artifacts that integrates visual and verbal elements—newsletters, product brochures, web pages, graphical novels, journal articles, resumes, software references, yellow stickies, etc. Yet, such visual-verbal discourse has only recently attracted the serious attention of research communities. Some of the relevant research questions include: Why do visual variations exist across different contexts? (e.g., Popular science looks different from Discover.) Why and how do visual styles change over time? (e.g., Magazines from the 1950s don't look like present day magazines.) Do visual elements have persuasive power? If so, what roles do they play in shaping an argument? How do people learn to communicate using visual-verbal artifacts? In this seminar, we will address these and other questions through readings and discussions on various threads of studies around the analysis of communicative artifacts that integrate visual and verbal expressions. We will review key research publications concerning visual-verbal communication from relevant disciplines, including professional and technical communication, rhetoric, argumentation, and literacy. Particular attention will be paid to descriptive methods (e.g., social-semiotic analysis, visual argument, and rhetorical structure theory) and the types of questions these methods can help us answer. Throughout the semester, students will be encouraged to explore the visual-verbal communication artifacts found around them and use those to connect class discussions to the practice of design. Required assignments include a brief bi-weekly response to the readings, several short analysis papers, and a longer term paper with a topic chosen by students based on their professional or research interests. Please see English Dept. for full course description.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-429 Introduction to Digital Humanities

Intermittent: 9 units

This course is a "learn by doing" introduction to questions and methods in digital humanities, with special emphases on common tasks in digital history, digital literary studies, library science, and cultural analytics. Students will likely partner with a national humanities organization to tackle real-world humanities problems while developing core computational competencies such as those required for gathering data (text mining, APIs), transforming data (OCR, regular expressions, natural language processing, image magick), file management (shell commands), data visualization (matplotlib, arcGIS), and more.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-431 Gender Play in Early Modern Drama

Intermittent: 9 units

The playhouses of early modern London offered access to an astonishing spectacle that would be difficult to find anywhere else in the city: men dressed as women, skillfully reproducing (but also exposing, interrogating, and refining) the significations that structure concepts of gender difference. In addition to this fundamental condition of performance and theatrical experience, the plots of the plays themselves regularly engaged with issues pertaining to gender and sexuality, an interest that runs through the raunchy satires performed by companies of adolescent boys, the innumerable comedies of cross-dressing and mistaken identity, and the equally numerous tragedies centered on problems of inequality and imbalances of power. This course will consider a wide range of drama from the period alongside a selection of readings in sexuality and gender theory, thus bringing early modern dramatists such as William Shakespeare and Thomas Middleton into conversation with contemporary thinkers such as Judith Butler and Sarah Ahmed. The body of core texts will include *Twelfth Night*, *The Merchant of Venice*, *As You Like It*, *The Roaring Girl*, *The Taming of the Shrew*, *The Tamer Tamed*, *The Island Princess*, *The Witch of Edmonton*, *The Silent Woman*, *Women Beware Women*, and *Galatea*. Please note: First-year students are prohibited from registering for this course. Sophomore students must obtain instructor permission. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-433 Love: A Cultural Introduction

Intermittent: 9 units

This is a course about the literary and cultural history of love. We will focus on romantic love, with an emphasis on how ideas about love have been a dynamic part of our social, political and economic world. Some of the questions to be addressed include: How, historically, did the idea of love become coupled with freedom? How did romantic love come to be considered the epitome of self-fulfillment and what are the contradictions in that idea? How has the idea of romantic love been mobilized on behalf of things like the state, the nation, capitalism or revolution? How do types of love function as a measure of belonging or deviance? How does the discourse of love enter different kinds of institutional arrangements, such as marriage or state citizenship? As a way to explore these questions, this course focuses on literature, reading canonical and non-canonical texts through philosophy, history, anthropology, sociology and law. Students will immerse themselves in an interdisciplinary range of material as they read, discuss and write about these representations. We will roam through cultural theory of affect, psychoanalytic notions of love, historical constructions of marriage, and feminist discussions of love and sexuality. The emphasis will be on Euro-American narrative traditions, but the final part of the course will include a contemporary global comparative context. Literary readings might include William Shakespeare, Jane Austen, Charlotte Bronte, James Baldwin, Toni Morrison, Arundhati Roy and Jeanette Winterson. This course is an advanced undergraduate-only English course with intensive reading. Note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission. Prerequisite: 76-101

76-435 Politics and Popular Culture

Intermittent: 9 units

Over the course of the last one hundred years what has been the influence of left-wing social movements on popular culture? Michael Kazin, in his recent best seller *American Dreamers* argues that the left has had a more powerful effect on culture than on politics. But what about the idea that cultural influence is inherently political? In this class we will read a mix of cultural history, film studies, music studies, literary studies, art history, television studies, and cultural theory. We will look at the intersection of radical movement politics and high modernism in the 1930s and 1940s. We will look at how left culture survived under the cloud of the blacklist. We will look at the Civil Rights culture and Feminist culture that emerged out of the 1950s and 1960s. Finally, we will look at how the left/right debates and struggles over the thirties, fifties and sixties have persisted into our current political/cultural narrative forms. Key texts for the course include Michael Kazin, *American Dreamers: How the Left Changed the Nation*, Paul Buhle, *Hide in Plain Sight*, the *Hollywood Blacklistees in Film and Television*, T.V. Reed, *The Art of Protest*, Susan Douglas, *Where the Girls Are: Growing Up Female with Mass Media*, Sasha Torres, *Black, White and In Color: Television and Black Civil Rights*, and Judith Halberstam, *The Queer Art of Failure*. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-438 The Wire: Crime, Realism, and Long-Form TV

Intermittent: 9 units

The HBO series *The Wire* (2002-2008) has been called the greatest TV show ever. Part of the first wave of "quality television" series by which HBO changed the way people conceived of the artistic possibilities of the medium, *The Wire* differed from its contemporaries like *The Sopranos* and *Six Feet Under* in its realism and its smaller audience. Unlike most other shows on television, *The Wire* addressed the racism, poverty, the failures of the criminal justice system, and other social problems head on. It was able to do this in part because it had enough time to develop complex story threads. This moment of TV history produced what I am calling "long-form" TV, in which narrative continuity was stretched over multiple seasons. TV in this form resembles 19th century novels that were first released serially in magazines and newspapers. In both cases, audiences waited expectantly for new episodes, since they could not be "binge-watched." *The Wire* was rooted in producer/writers David Simon and Ed Burns' experiences in Baltimore, where the former had been a crime reporter and the latter a police detective. Simon has said that he made the series in order to tell truths about the city he could not tell in the newspapers. This course will consider the wire in the context of realist fiction of the 19th century, twentieth-century crime fiction, earlier TV crime series, and other long-form TV, including *Mad Men*. We will try to explore *The Wire's* realism, its continuing appeal, and its impact. We will probably watch 3 seasons of *The Wire*. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-439 Seminar in Film and Media Studies

Intermittent: 9 units

Topics vary by semester. Fall 2023: *Novelistic Television* - Topics vary by semester. Fall 2023: *Novelistic Television*: In this course we will look at television series defined by narrative complexity developed over the course of a season and beyond. We will watch whole seasons of such shows as *The Sopranos*, *Mad Men*, *The Wire*, *Six Feet Under*, and *Slings and Arrows*, which bear greater similarity to the novel than to traditional, episodic TV. We will trace the development of the novelistic form of television from the first wave of "quality television" series in the 1990s, in which HBO changed the way people conceived of the artistic possibilities of the medium, through the 2000s, when *The Wire* and *Mad Men* fully exploited the new form, and finally into the streaming era, when it has become common but less innovative. We will read media history and theory, and narrative theory to develop an understanding how and why the new form emerged. We will endeavor to understand these shows as expressions of and commentaries on the social and political conditions under which they were produced. We may read a novel or two for purposes formal comparison, and we will watch some episodes of more traditional TV series. Likely theorists include Raymond Williams, Linda Williams, Jason Mittell, Pierre Bourdieu, and Fredric Jameson. Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-440 Postcolonial Theory: Diaspora and Transnationalism

Intermittent: 9 units

Arjun Appadurai argues that one of the primary transformations in this period of globalization has been in the capacity for people to imagine themselves or their children will live and work in places other than where they were born. Although the novel has long been considered a national form, contemporary novels frequently represent transnational mobility, both in their plots and as global commodities. A significant body of contemporary fiction focuses on imaginative and physical movement across national borders. This global literature course combines literary and theoretical readings to examine the experiences of transnationalism and diaspora. Theories of transnationalism look at the interconnections that cut across nations. The concept of diaspora, a term first used to reference the movement of a people out of a homeland, has become a way to think about the identities of immigrants, migrant workers, and refugees. Readings for the course will be drawn from a diverse group of writers from around the globe. Literary readings might include works by Caryl Phillips, Jamaica Kincaid, Christina Garcia, Nadeem Aslam and Jhumpa Lahiri; theoretical readings might include works by Salman Rushdie, Paul Gilroy, Gloria Anzaldúa, Arjun Appadurai, Inderpal Grewal and Avtar Brah.

76-441 Theorizing Sexuality

Intermittent: 9 units

This course offers a foundation in the history of theorizing sexuality that brings us from the Greek classical concept of man/boy love, through medieval concepts of the "one-sex body," and up to contemporary transgender theory. We will read canonical theories of sexuality in the modern period, such as Freud's psychoanalytic *Three Essays on Sexuality* and Michel Foucault's revisionist *History of Sexuality*. To ground our theoretical investigations in social and historical context, we will focus on three discursive sites: the feminist "sex wars" of the 1980s, the theory and practice of "trans" both gender and sexuality from modern and contemporary periods, and late 20th and 21st century queer concepts of sexuality.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

76-443 Restoration & 18th-Century Theatre

Intermittent: 9 units

London theaters turned on their lights (or more properly, lit their candles) in 1660 when the Puritan regime ended and Britain returned to monarchical rule. The newly opened theaters quickly became spaces for political and social performances by both actors and audiences. The theater was the place not only to see plays but to hear the latest gossip about the glitterati of the court, to monitor political plots, and to speculate on which pretty actress was current mistress to the King. It was literally a space in which society performed itself, to itself. We will look at the development of the theater as an important social institution and trace its development, up to the mid 1700s, as a media hub that spread its tentacles into newspapers, visual materials, and other popular culture media. Of course, we will read some of the most important plays of this time period, but we will also pay attention to the print and visual culture that grew up around and in response to the theater. In addition to building knowledge about this important chapter in the development of modern media culture, this course will introduce students to performance studies as a framework for the study of culture in any historical period.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-444 History of Books and Reading

Intermittent: 9 units

Rather than putting an end to the book, digital media have had the oddly exhilarating effect of making us look at all kinds of print, past and present, through newly focused lenses. This course will introduce you to the history of books and reading, a cross-fertilizing field of study that is having an impact on many disciplines, from the history of science to literary history, cultural studies, and the arts. Scholarship in this still-emerging field will include work by Roger Chartier, Michel Foucault, Elizabeth Eisenstein, Pierre Bourdieu, Michel de Certeau, and the current scholars who appear in one of our key books, "Interacting with Print: A Multigraph." We'll also read primary texts by Joseph Addison, Jane Austen, Samuel Coleridge, and Wilkie Collins to see how differing modes of print and reading became highly contested cultural and political matters in the eighteenth and nineteenth centuries. Other topics include the division between new reading publics and their ways of reading books; important changes in book production, typography, printing methods (hand-press to steam press). Such knowledge of the history of print has become especially crucial in an era of emerging "new media" and the field of digital humanities in the university. Two papers will be required: one shorter paper (5-7 pp.) and a longer research paper on the uses of books and print by producers and readers. Though the course meets in Baker Hall, you will have hands-on experience with early books and other forms of print as we also meet periodically in the Rare Book Room at Hunt Library.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-445 Milton

Intermittent: 9 units

Although censored and reviled by many in his own day, John Milton (1608-1674), author of *Paradise Lost* among other powerful anti-monarchical writings of the English Revolution, has influenced writers as varied as William Blake, Mary Shelley, Thomas Jefferson, Friedrich Engels, C.S. Lewis, Malcolm X, and Philip Pullman. This course will investigate what has made Milton a writer at once so much imitated and beloved by his admirers and loathed and denigrated by detractors. The bulk of this course will center on a careful, challenging, and chronological reading of Milton's works, primarily *Paradise Lost* but also his great shorter poems including *Lycidas*, *Paradise Regain'd*, and *Samson Agonistes*, and selections of his voluminous prose (*Areopagitica*, *Of Education*, *Tenure of Kings and Magistrates*, *Readie and Easy Way to Establish a Free Commonwealth*). Studying Milton's development as a poet, controversialist, and pamphleteer, students will examine Milton's contexts (chiefly, literary, political, and theological) in order to gain further insights into the complex relations between Milton's 17th-century world and his major poems and prose. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-446 Revenge Tragedy

Intermittent: 9 units

Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include the following plays: *Thyestes* (Seneca), *The Spanish Tragedy* (Kyd), *Titus Andronicus* (Shakespeare), *Hamlet* (Shakespeare), *The Revenger's Tragedy* (Middleton), and *The Duchess of Malfi* (Webster). We will also read a selection of critical essays and related literature from the period.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-107 and 76-108) or (76-106 and 76-108)

76-448 Shakespeare on Film

Intermittent: 9 units

The dramatic works of William Shakespeare have inspired an extraordinarily rich and varied cinematic legacy that began in the era of silent films and now boasts masterpieces by directors such as Akira Kurosawa, Roman Polanski, Peter Greenaway, and Orson Welles, not to mention history-making performances by icons including Marlon Brando, Elizabeth Taylor, Laurence Olivier, Al Pacino, Leonardo DiCaprio, and Ian McKellen (among many others). This course will consider a selection of key Shakespeare films alongside critical readings centered on questions of adaptation and performance. As we watch and read together, we will work toward a broader understanding of what Shakespearean drama means in a 21st century context, and how film has helped to shape the author's massive cultural impact.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-449 Race and Media

Intermittent: 9 units

This course will introduce students to useful methodological approaches to analyze race and representation within a variety of media formats. Media in this course is understood broadly: technologies used to store and deliver information. With this rather broad understanding in mind our course will look at how artists and intellectuals use discrete formats (print, film/video, electronic, and other recording mediums) to imagine, remediate and study the circulation of racialized bodies and identities within global capitalism. We will also think about the concept of race itself as another, particularly problematic "media" format used to store and deliver information about the human for political, economic, ideological and juridical purposes. The class will be organized around specific material and "immaterial" media objects that will allow us to explore the processes of (re)mediation that characterize racialized bodies and formats. We will look at a range of formats from literature and music to film, television, and social media. The course is structured to provide both a chronological and historicist approach to the discourses that define race and media. More than likely, we will watch and (or) read the works of D.W. Griffith, Nella Larsen, Melvin Van Peebles, Lizzie Borden, Audre Lorde, Claudia Rankine, Alex Rivera and Nia DaCosta. We will also read the theoretical works of Jacques Ranciere, Huey P. Newton, Dallas Smythe, Lisa Gitelman and Michael Gillespie, Simone Browne, Theodore Adorno, Sara Ahmed and many others. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-450 Law, Culture, and the Humanities

Intermittent: 9 units

"I'm not a lawyer, but..." How many times have you heard this disclaimer, closely followed by a lay analysis of law? This course, an introduction to the cultural study of law for graduate students and advanced undergraduate students, can be seen as an introduction to what goes into the making of such a statement. Where do we get our ideas about law? What do we mean when we say "law"? What counts as law? How does culture influence law, and law, culture? And to what degree should historical context condition any answers we might be tempted to give? Students in the course will study works in a range of genres (novels, plays, poems, judicial opinions, pamphlets) and develop methods for investigating ways that law and culture have been made by one another from the 16th-century to the present. Readings will include influential theoretical accounts of law (Aristotle, Hobbes, Cover, Habermas, Bordieu, MacKinnon, Alexander), canonical texts in Law and Literature (Shakespeare's Measure for Measure, Melville's Billy Budd, Kafka's The Trial) and some "weird fiction" by the novelist/legal theorist China Mi and #233;ville. As a counterpoint to the fiercely anti-historical "law and economics" movement, however, the course will put special emphasis on rooting intersections of law and culture in rich historical context, considering both local and international legal contexts (sometimes in fairly technical detail) alongside so-called "ephemera" of culture. Students will tackle the especially fruitful "case" of Renaissance Britain before developing final research projects, whether on the Renaissance or another period of their choosing.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-452 Generations and Culture

Intermittent: 9 units

We frequently hear about generations and #8212;the Millennials and their multitasking, Gen X and their minivans, and the Baby Boomers and their self-satisfaction and #8212;but generations have usually been ignored in cultural studies. Yet generations have significant impact on cultural tastes, consumer choices, and political views, as a good deal of research shows, and identity, alongside other factors such as race, class, gender, sexuality, ethnicity, and abledness. This course will study the theory of generations, as well as novels and films that tell us about generations. Please note: first-year students are prohibited from registering for this course. Sophomore students require instructor permission.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-453 Literature of Empire

Fall: 9 units

Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's Frankenstein and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's Lord Jim, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in The Painted Veil. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's Mrs. Dalloway. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-107) or (76-106 and 76-108)

76-454 Rise of the Blockbuster

Intermittent: 9 units

The term "blockbuster" has been a part of the American film industry for over sixty years, but, like "pornography," it's extremely difficult to define from a critical standpoint. For most of the viewing public the "we know it when we see it" definition seems to suffice. In an academic sense, however, such vagueness is problematic. This course will explore the idea of the "blockbuster" over time and across cultural boundaries. What is the origin of the concept? What is the structural impact of the "blockbuster" on the film industry? How does the meaning of the term change from genre to genre? Is it a genre in and of itself? How does a "blockbuster" reinforce our cultural conceptions? How might the concept change in the future? What does all of this tell us about ourselves? This course will draw examples from across the history of film in order to develop a holistic understanding of what the term might encompass from a variety of perspectives. By thoroughly discussing a wide selection of texts we will be able to better understand the ways in which the "blockbuster" has influenced the film industry, how the concept has both manifested itself and changed over time, and how it has shaped our cultural perspectives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisite: 76-101

76-456 Independent Study in Film & Media Studies

All Semesters

TBA

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-107 and 76-108)

76-457 Rhetorical Invention

Fall: 9 units

Rhetorical invention refers to the discursive process of inquiry, discovery, and problem solving, or how we decide what to say, what arguments to advance, and what means of persuasion to use in any situation. Although invention is centrally important to rhetoric without which it becomes a superficial and marginalized study of clarity, style, and arrangement from the Scientific Revolution and Enlightenment through the mid-twentieth century invention all but disappeared as a topic of rhetorical study under the pressure of the view that invention should be exclusively governed by deductive logic and the scientific method rather than rhetorical considerations such as audience or the figurality of language. This repudiation of rhetorical invention fundamentally shaped modern thought and continues to influence the ways we think and communicate today. In this course, we begin by examining the status of rhetorical invention in the development of modern thought before focusing on various scholarly efforts to revive a rhetorical understanding of invention from the mid-twentieth century forward, surveying a variety of contemporary theories of rhetorical invention including those promoted by postmodern, posthuman, and digital rhetorics. The course is designed to explore the central importance of invention to contemporary rhetorical theory through a pairing of historical and contemporary readings.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-460 Beginning Fiction Workshop

Fall and Spring: 9 units

In this writing-intensive workshop students will be laser-focused on producing and polishing their own fiction. We'll complement our workshops with readings from masters of short fiction and novels, with an eye on sharpening our own facility with dialogue, structure, and voice. Each student must be prepared to constructively critique and deconstruct her/his peers' work, as well as actively contribute to class discussions about the elements of craft that undergird successful works of fiction. Each student will be expected to produce a portfolio of original writing (short exercises originating from thematic prompts and a substantial story) by the end of the semester.

Prerequisite: 76-260 Min. grade B

76-461 Immigrants, Migrants, and Refugees

Intermittent: 9 units

Contemporary literary writers offer vibrant portrayals of questions around identity, displacement and belonging that accompany immigration, transnational labor (and love) migration, and asylum claims. While British and American works in the late 20th century focused primarily on questions of identity and assimilation for new immigrants, contemporary literary works are increasingly examining the regulations of states, the permeability of border, the experiences of detainment, and the less visible parts of transnational labor and commodity exchange. This is primarily a contemporary English, American and Anglophone global literature course that includes fiction, poetry, and drama; the course also includes non-fiction theoretical, journalistic and memoir readings, as well as documentary film, that will help us analyze the experiences and structures of transnational migration. Possible readings might include Juno Diaz, Julia Alvarez, Celeste Ng, Dina Nayeri, Chimamanda Ngozi Adichie, Jhumpa Lahiri, Viet Thanh Nguyen, Sunjeev Sahota, Nolo Violet Bulawayo, Shailja Patel, and Caryl Phillips. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

76-462 Advanced Fiction Workshop

Fall and Spring: 9 units

This course will give you experience reading and writing in two genres: fiction and creative nonfiction. The course is discussion based, and several classes per month will be devoted to generative, in-class writing exercises, which students will then work on as drafts to revise. Readings will include novels, stories, essays, and short journalistic pieces. Attendance and participation is mandatory. If you're interested in delving more deeply into the craft and art of these prose genres, and willing to put the time in to develop your own writing, this is a good class for you. I stress that a classroom is a community, and emphasis will be on establishing real connection between students. We will see how writing can help create and build on these connections between people, and serve as a tool for healing during a particularly rough time in our culture.

Prerequisites: 76-260 Min. grade B and 76-460 Min. grade B) or (76-460 Min. grade B and 76-261 Min. grade B)

76-464 Creative Nonfiction Workshop

Intermittent: 9 units

This course will deepen your understanding of the possibilities for writers engaged with the genre of Creative Non-Fiction. We'll be reading books and essays from a variety of writers, including CMU graduate Neema Avashia, whose collected book of essays has been recently published. We'll read essays and memoir that illumine the formation of identity, that question the status quo, that celebrate human connection, and that often shine a light on injustices shaping our world. Students will write their own essays and memoir, and class will be conducted as a discussion where all will be expected to show up regularly, and remain engaged so as to create a place where students get to know one another and support each other as writers. Prerequisites: 76-460 Min. grade B or 76-262 Min. grade B or 76-365 Min. grade B or 76-260 Min. grade B or 76-265 Min. grade B or 76-261 Min. grade B

76-465 Advanced Poetry Workshop

Fall and Spring: 9 units

In this workshop, we'll investigate what's possible in poetry, as participants examine their relationship to the poetic practice both as readers and as writers. Through writing exercises, discussion, and readings, we will explore the diverse landscape of contemporary poetry, and experiment with form and technique. As we study different methods of making a poem, and different notions of what makes a poem, and what makes a poem great, participants will work to discover imaginative ways of approaching the line and the page.

Prerequisite: 76-365

76-467 Crime Fiction and Film

Intermittent: 9 units

This course will be concerned with hardboiled crime fiction in print and on screen. The hardboiled emerges in Ernest Hemingway a distinctive literary style, and about same becomes a formula for pulp crime fiction. The language and attitude of the hardboiled became associated with urban gangsters in films such as *The Public Enemy*. Newspaper crime coverage beginning in the 1920s becomes increasingly frank in both its language and photographic coverage of crime. These various elements will be the material for a new kind of literature represented Dashiell Hammett, James M. Cain, and especially Raymond Chandler, and for a cycle of films that owe much to their work, film noir. Chandler was responsible for invention of one of most enduring types in American fiction, the hardboiled detective. The course will focus on Chandler and the crime stories after him that make various uses of that type and the formula that has become associated with it. Throughout the course we will consider the social and political contexts in which these cultural forms developed, and what cultural work the hardboiled performed. We will be especially interested such questions as the function of the misogyny typical of much of it, the different representations of race by white and black artists, the representation of police, whether the hardboiled is best understood as having a working-class affiliation, and the degree to which its various manifestations might be called realist. NOTE: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-468 Space and Mobilities

Intermittent: 9 units

This course will investigate space and movement as social constructions. Space is something dynamically created that may be interpreted for the ways it creates meaning, while movement reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course might include discussions of migrants and state borders, cultural constructions of transport, the poetics of space, and the dynamic mapping of the city through movement and sound. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's *Dreaming in Cuban*, W.G. Sebald's *Austerlitz* and Teju Cole's *Open City*. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission. Students across disciplines are encouraged and may work on a final project related to their primary field.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-469 Screenwriting Workshop

Spring: 9 units

This semester will begin with a review of the fundamentals of screenwriting, including character development, scene construction, dialogue, and story structure. Student work will include exercises that encourage writers to take creative risks with genre, tone, character, and structure, one collaborative project, and two short scripts. We will also view mainstream, personal, and experimental narrative films in both American and international cinema.

Prerequisite: 76-269 Min. grade B

76-472 Topics in Journalism: Storytelling in a Digital Age

Spring: 9 units

Advanced Journalism students will learn how to plan and execute long-form news feature stories from the ground up, starting with recognizing a promising idea, organizing a solid proposal then ultimately producing a publication-ready report that is both accurate and compelling. We will focus on four types of feature stories over the course of the semester: a trend story, a profile, an explanatory report and a data-driven investigative story. Each will require strong news judgment and solid writing skills, plus the ability to adapt as some story leads unexpectedly come to a dead end while promising other angles rise to the surface. Don't be surprised if the final product is notably different than the original idea; that's often the path of the most successful reports. While each student is responsible for his or her work, class sessions will be highly collaborative as ideas and strategies are critiqued with an eye toward helping all students achieve their best work.

Prerequisite: 76-372

76-473 Rhetoric & the Construction of Race

Intermittent: 9 units

In their seminal book on race, Michael Omi and Howard Winant write that race is "socially constructed and historically fluid." This course takes their assertion seriously by examining the role of communicative practices in constructing race, from discourses around the NFL national anthem protests to dominant discussions around transnational and transracial adoption. We'll look for common themes in the discourse around certain events and practices, asking why certain ideas or tropes are used and repeated, and what historical, social, cultural, and political associations inform these tropes that help them to perpetuate racial stereotypes in popular culture without overtly claiming racism. Students will practice thinking critically about everyday cultural narratives, and produce a final paper identifying the work one such set of narratives does to shape reality and create, reinforce, or perpetuate the construction of racial meanings.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-106 and 76-108) or (76-107 and 76-108)

76-474 Software Documentation

Spring: 9 units

This course teaches theory, techniques, and best practices for creating software documentation. We will learn to plan, architect, write, and publish audience-appropriate user assistance, while applying concepts and approaches like minimalism, topic-oriented authoring, single-source publishing, content reuse, and metadata. Students will complete homework assignments and larger projects to reinforce principles and provide experience in all phases of the software documentation lifecycle. Readings and class discussion will bridge theory and practice.

Prerequisites: 76-271 or 76-270

76-475 Law, Performance, and Identity

Intermittent: 9 units

Although rhetoric and law have long been closely associated, the modern professionalization of law has often promoted the idea that legal discourse is not rhetorical but a rigorously defined technical discourse that can be applied free of social, cultural, or political considerations. This view of legal discourse is disputed by critics who point out the figurative aspects of legal language, the relevance of character, emotion, and narrative in legal communication, and the ways in which law protects social structures of power such as race, class, and gender privilege. The course broadly examines the fraught relationship between rhetoric and law by considering the ways in which a variety of legal discourses serve to construct and reinforce identities, with a particular focus on the ways in which legal systems are portrayed to reflect the ideals of democracy to suit particular foreign relations goals. We begin by studying the ways in which Cold War foreign policy goals influenced desegregation and civil rights discourse in the United States, then we turn to the ways in which the prosecutions of deposed authoritarian rulers in various regions of the globe have been orchestrated to persuade global audiences that emerging democracies observe the "rule of law" for purposes of garnering international support. Alongside primary sources of legal discourse, we will study a selection of interdisciplinary scholarship about the relationship between rhetoric and law. Students write a two-stage research paper on a topic of their choosing regarding the relationship between legal discourse and the construction of identity. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-476 Rhetoric of Science

Fall: 9 units

This course explores questions about scientific argument and communication that are of interest to students in the sciences, rhetoric, and professional/technical writing. These include questions like: How are scientific arguments structured? How is scientific information and argument transformed when it moves from research papers for specialist audiences to publications for non-specialists? How does the social, historical, and cultural context of science shape the way it is communicated and/or argued? What contributions do visuals make to scientific argument and communication? To investigate these questions, we will be examining a wide variety of real-world communications in and about science as well as texts in rhetoric, history, and philosophy of science.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

76-481 Introduction to Multimedia Design

Fall: 12 units

There is increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. This class will provide students with the opportunity to develop the ability to create and analyze multimedia experiences that merge text, spoken voice, music, animation and video. Students will be introduced to the basic concepts and vocabulary of motion graphics, as well as the practical issues surrounding multimedia design and digital storytelling through a series of hands-on projects involving various contexts. Students will explore what it means to write for a dynamic medium and how to take advantage of elements of time, motion and sound to help expand their visual communicative skills. The essentials of Adobe After Effects will be taught in order to build the skills necessary to complete assignments, explore multimedia possibilities and foster each student's unique creative voice. Adobe Premiere and Audition will be employed to support specific tasks. Students will also be taught to capture their own original images, video and narration audio to craft the elements of their projects. It is helpful to have some prior basic experience with Photoshop or Illustrator. In-class discussions, 2 group workshops and critiques are an essential part of this course.

Prerequisites: (76-271 or 76-270) and (76-391 or 51-262 or 51-261)

76-483 Research Methods in Technical & Professional Communication

Fall: 9 units

This course provides you with practical, hands-on experience with designing, collecting, and analyzing research in Technical and Professional Communication. These same research methods are also applicable to Writing Studies and classroom research. We will go into depth on three main methods in this class: interviews, surveys, and think-aloud protocols. In addition, we will touch on focus groups, eye-tracking analysis, and collaborative analysis techniques. More specifically, in this class you will learn how to design well-worded questions that produce reliable information; critically reflect on and improve your interview technique; explore software designed to aid in open-ended analysis of qualitative data; design an A/B (or control/experimental) study; write a data-driven research report, and experiment with a range of data collection techniques. Students taking the course for 12-units will have additional readings that look at how these research methods have been applied in Technical and Professional Communication and Writing Studies.

Prerequisites: 76-270 or 76-271

76-484 Discourse Analysis

Fall: 9 units

Discourse is a focus of study in most of the humanities and social sciences, and discourse analysis is practiced in one way or another by anthropologists, communications scholars, linguists, literary critics, and sociologists, as well as rhetoricians. Discourse analysts set out to answer a variety of questions about language, about writers and speakers, and about sociocultural processes that surround and give rise to discourse, but all approach their tasks by paying close and systematic attention to particular texts and their contexts. We are all familiar with the informal discourse analysis involved in paraphrasing the meanings of written texts and conversations, a skill we learn in writing and literature classes and in daily life. Here we ask and answer other questions about why people use language as they do, learning to move from a stretch of speech or writing or signing outward to the linguistic, cognitive, historical, social, psychological, and rhetorical reasons for its form and its function. As we look at resources for text-building we read analyses by others and practice analyses of our own, using as data texts suggested by the class as well the instructor. In the process, we discuss methodological issues involved in collecting texts and systematically describing their contexts (ethnographic participant-observation and other forms of naturalistic inquiry; transcription and "entextualization;" legal and ethical issues connected with collecting and using other people's voices) as well as methodological issues that arise in the process of interpreting texts (analytical heuristics; reflexivity; standards of evidence). The major text will be Johnstone, Barbara. 2008. *An Introduction to Discourse Analysis*. 2nd ed. (Malden, MA: Blackwell Publishers). Other reading will be made available as .pdf files.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-108 and 76-106) or (76-108 and 76-107)

76-485 The New Public Sphere

Intermittent: 9 units

Public deliberation about issues that matter to us is at the heart of the rhetorical tradition. But is meaningful public dialogue really a live option in a divisive, media-saturated world of sound bites addressed to partisan publics? Moreover, is the process of debate, deliberation, and decision making (in which the best argument wins) really the normal (or even ideal) model? Or can people use local public spaces to develop new, more inclusive positions? How might such a process create a boundary-crossing public in which diverse groups enter intercultural deliberation around racial, social, economic or environmental issues? This course looks at critical ways people use rhetoric to take liberating social action within local publics. From the debate spurred by Habermas's canonical version of the public sphere, we move to a feminist "rereading" of the Greek Sophists, to more contemporary studies of deliberation in workplaces, web forums, grassroots groups, new media, and community think tanks. Working as a rhetorical consultant into the meaning making process of a local public of your choice, you will also learn how to support your inquiry with a variety of methods, from an interactive activity analysis to a more focused probe into the social/cognitive negotiation conflict may require.

Prerequisite: 76-373

76-486 Argument Theory

Intermittent: 9 units

Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: (76-373 and 76-101) or (76-373 and 76-102) or (76-373 and 76-106 and 76-107) or (76-108 and 76-107 and 76-373) or (76-106 and 76-108 and 76-373)

76-487 Web Design

Fall: 12 units

The World Wide Web is a vast collection of information, far more than we can comfortably handle; even individual websites can pose so much information that they become overwhelming. In this client-facing, project-oriented class, we aim to look at ways to tackle this problem, and design content for the web that is easy to access and digest. We will look at how websites manage and present organized information, with an eye to understanding what works well. We will use methods to learn who is using a website and why, and develop our toolset to test our decisions when implementing a new design. Along the way, we will develop a familiarity with the core web technologies of HTML5 and CSS3, with discussion of graphics, sound, social media, and other tools to enrich our presence on the World Wide Web. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Prerequisites: (76-101 or 76-271 or 76-272 or 76-270 or 76-102) and (51-262 or 51-261 or 76-382 or 76-391)

76-491 Rhetorical Analysis

Intermittent: 9 units

Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-492 Rhetoric of Public Policy

Intermittent: 9 units

This course explores a rhetorical approach to public policy which focuses on the interconnected role that data, values, beliefs, and argument play in the policy process. From this perspective we will examine the important public debate over the pros and cons of various forms of energy production including nuclear, natural gas, and solar. In these investigations, we will explore questions like "How do policy makers use rhetoric to shape public perspectives on energy production?" "How can rhetorical approaches to argument function as tools for policy analysis and development?" And "What role does technological expertise play in public debate?" To pursue these questions, we will be reading works in rhetorical theory and public policy and applying the concepts and methods in those works to exploring primary artifacts of public argument like records of public hearings, social media memes, handbooks designed by activists, and stories about energy production in the popular media.

Prerequisites: 76-101 or 76-102 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

76-494 Healthcare Communications

Fall: 9 units

Healthcare communications is designed for students with an interest in how medical and health care information is constructed and transferred between medical experts, health care providers, educators, researchers, patients and family members who are often not experts but need a thorough understanding of the information to make important health decisions. Throughout the course, we will explore the interactions of current theory and practice in medical communication and the role of writing in the transfer and adoption of new therapies and promising medical research. We will also study how the web and social media alter the way information is constructed, distributed, and consumed. We will examine the ways medical issues can be presented in communication genres (including entertainment genres) and discuss how communication skills and perceptions about audience can influence clinical research and patient care. Additionally, we will explore clinical trials, grant writing, and press releases, and will feature guest speakers from these fields will discuss their experiences.

Prerequisites: 76-271 or 76-395 or 76-270

76-495 Other People's Words: The History, Theory, and Practice of Interviews

Intermittent: 9 units

In literary studies, we usually draw our research from books and articles, or sometimes from documents in archives. But one other way to find out information is from interviews. Historians, anthropologists, and journalists use interviews, albeit in different ways. How might we apply their methods to literary study? This course will look at different modes of interviewing. You will also conduct various kinds of interviews yourselves. Thus the course will be a mix between a criticism course and a workshop. Through the semester you will be responsible for conducting and editing one long-form interview with a person about art, literature, or another field. In addition, you will develop a project conducting multiple interviews on a topic. Lastly, you will build a portrait or report drawn from one of those projects.

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-496 Research Methods in Rhetoric & Writing Studies

Intermittent: 9 units

NOTE: This course is only available for seniors with special permission. This course is a survey introduction to historical, empirical, text-based, and qualitative methods of inquiry used in the fields of rhetorical and writing studies. We will read broadly to understand the philosophical questions, research traditions, practical applications, and innovative directions that shape the field, exposing students to a range of methods and methodologies. Studies of rhetoric, writing, and literacy have evolved tremendously, and we will examine approaches for how to trace, analyze, and critique the use of meaning making in a variety of cultural, political, workplace, technological, and pedagogical contexts. By the end of the course, students will develop a sense of how to put together an effective research project on their own and design and articulate the research methods and methodologies appropriate to that study. Throughout, we will ask a fundamental question: How do rhetoric, writing, and literacy work and for what consequences?

Prerequisites: 76-101 or 76-102 or (76-107 and 76-106) or (76-108 and 76-106) or (76-108 and 76-107)

76-511 Senior Project

Intermittent: 9 units

Seniors in all four majors within the English Department may, with faculty permission and sponsorship, design and complete an original, student-planned Senior Project. Creative Writing majors may work on a book-length manuscript in fiction or poetry. Students in all majors within the Department may also, with the permission of a faculty advisor who will supervise and sponsor the project, develop and complete senior projects that involve either traditional academic research or investigations of problems in professional or technical communication.

76-700 Professional Seminar

Fall: 3 units

This weekly, 3-unit seminar is designed to give professional and technical writing majors an overview of possible career and internship options and ways to pursue their professional interests. Each session will feature guest presenters who are professionals working in diverse communications-related fields such as web design, journalism, public relations, corporate and media relations, technical writing, medical communications, and working for non-profits. The visiting professionals talk about their own and related careers, show samples of their work, and answer student questions. The course is required for first-year MAPW students and is open to all English undergraduates, who are urged to participate in their sophomore or junior years to explore options for internships and careers.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-702 Communication Support Tutoring Practicum

Fall

The Communication Support Practicum is designed to introduce students to communication scholarship and pedagogy as well as the methods and theories that inform them for the purpose of communication support and tutoring in CMU's Student Academic Success Center. Students will explore communication (written, oral, and visual) in multiple disciplines and genres with a focus on gaining knowledge and skills to respond to communicators and their texts. Lectures, discussion, and assignments will offer a chance to think critically about tutoring practices and the ideologies and values on which they are based as well as ways to challenge the bias inherent in them. There will be many occasions to reflect on and evaluate tutoring skills, observe others in tutoring situations, and practice a variety of methods that consider the different needs of communicators. Students will gain awareness of how various spaces, identities, technologies, and abilities inform textual production as well as how to create a meaningful response to meet the diverse needs.

Course Website: <https://www.cmu.edu/gcc/faqs/index.html> (<https://www.cmu.edu/gcc/faqs/>)

76-708 Literary Journal Publishing

All Semesters

In this course, students will learn about the landscape of and publication process for literary journals in the United States. We will read a variety of literary journals in print and online, will host guest speakers, and will do a variety of hands-on activities related to editing and publishing. Students will gain experience by working on The Oakland Review, an international literary journal run out of CMU, in capacities as varied as editorial, design and production, or promotion. If you are interested in registering for this course, please go to the Course URL and fill out the questionnaire. Thank you.

Course Website: <https://form.jotform.com/CMUEnglish/literary-journal-publishing-course> (<https://form.jotform.com/CMUEnglish/literary-journal-publishing-course/>)

76-719 Environmental Rhetoric

Fall

Should you take a hike or seize the mic? Environmental rhetoric combines commitment with contention. We start by exploring its multiple discourses, from Muir's vision of conservation, to Leopold's introduction of ecology, to Carson's call for public action, to contemporary scientific research and competing public discussions. To uncover their hidden logic, we study rhetorical strategies first, for analyzing arguments (over issues such as wolves, clean water, or sustainable design), and then for communicating risk (in the face of climate change, fracking, as well as wind power). In response, this course will prepare you to act as a research-based rhetorical consultant for a group of your choice, analyzing the issues and arguments it faces, in order to propose a rhetorically effective response, supported by your own imaginative prototype of a brochure, web page, press release.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-720 Leadership & Organizational Communication

Intermittent

Please note: In order to register for this course, students must have had an internship with an organization prior to registration. Even as most organizations continue to change, one constant is the importance of effective communication. Upward, downward, and lateral communications are the lifeblood of organizations. If you are in a leadership position, communication become your key tool for managing teams, improving performance, and creating change. In any position, you can spearhead progress by designing effective documents and improving existing communication practices. Proficiency in written and oral communications tends to be recognized and rewarded in organizations. Combined with the ability to leverage formal organizational structures and social networks, it helps one excel, and thrive, in organizations. This course is designed as an overview to the field of organizational communication with an emphasis on leadership roles and behaviors. The content will blend the conceptual with the practical. It will focus on problems that are likely to arise in the workplace and ways to solve them through communication. The students will build a portfolio of "solutions" that will demonstrate their evolving skills of applying rhetoric in organizational contexts. Specific topics will include the attributes of great communicators (including leaders and managers as communicators), the challenges of communicating in organizations as we play particular roles (e.g., individual contributor, manager or team member), ways to build credibility and enhance internal resumes, and techniques to master communication requirements related to performance management processes, conflict situations, and changing organizational culture and design. We will also explore a myriad of organizational issues such as communicating across generations and cultures, communicating externally, and communicating through technology.

76-727 Equity & Communication: Strategies for Institutional Change

Spring

Communication is always embedded in power relationships with unstated social rules that govern who is able to say what when. But communication also offers us a tool for rewriting oppressive social scripts. In this class, we will look both at inequities built into our communication and strategies for overturning these inequities. The focus will be on practical actions that you can take to improve your school, workplace, or extracurricular groups. Our readings will come from diverse sources and fields, including sociolinguistics, psychology, education, organizational communication, rhetoric, and writing studies. While our readings might occasionally depress (or enrage) you, the overall focus of the course will be optimistic, challenging you to imagine solutions to the problems we discuss.

76-729 Performing Race in Early Modernity

Intermittent

The earliest known use of the term "white" in reference to Europeans occurs in *The Triumphs of Truth*, a 1613 play by Shakespeare's contemporary, Thomas Middleton. In addition to suggesting an important connection between race and drama in 17th-century England, this simple historical note raises a range of questions that have a direct bearing on some of the most pressing issues of the 21st century: Where do ideas about race come from? By what processes do the distinctions of racial concepts emerge, evolve, calcify, and mutate? How does the conceptualization of race relate to media? How do racial representations bolster and conduct political power? In this course, we will broach these questions by taking a close look at the race-making function of drama in early modernity, a period when race was an inchoate, incipient concept, caught up with the emergence of colonialism, capitalism, and increasing interconnection between peoples, cultures, and worlds. As we think, read, and converse together, we will endeavor to come to terms with the problems and paradoxes of racial representation in the early modern theater, a forum that offered access to innovative, daring thinking about human equality and ethical responsibility, but was also a site for the perpetuation of hateful stereotypes and exploitative theories of white supremacy. In a wide-ranging survey of drama, historical documents, and contemporary criticism, we will work toward an understanding of how race-based concepts operated in the theater, and how the drama early of modernity continues to influence thinking about race in our own time. This course meets the Dietrich College Reflecting Gen Ed requirement.

76-731 Dissenters and Believers: Romantics, Revolution, and Religions

Intermittent

This course examines the relation of Romantic writing to religion in the age of revolutions. We will read a number of Romantic-age writers: William Blake, S. T. Coleridge, William Wordsworth, Edmund Burke, Monk Lewis, Percy Shelley and #8212; in relation to the most "orthodox" religious modes (Anglican, Catholic, Lutheran, and Evangelical) and the most "heterodox" (Enthusiasm, Rational Dissent, Unitarianism, Deism, Pantheism, or atheism). We will also distinguish between "religions" (as formally institutionalized) and "religiosity" (defining religiosity as more diffused or displaced feelings, ideas and practices that are often not clearly marked as religious or related to any one institutional religion. Two papers are required.

76-749 Climate Fictions

All Semesters

During the last 20 or so years, a new kind of fiction has emerged responding to scientific models of climate change. Climate fiction, or "cli-fi," most often imagines a future in which nothing has been done or done soon enough to limit global warming. Much of this literature fits into the broad genre of science fiction, but some of it uses other fictional modes, including realism and postmodernism. This course will look at a variety of fictional approaches to climate change, including a few in visual media. We will consider why fiction is a necessary component of our understanding climate change: computer models are fictions of a sort but also whether and how fictional narratives such as novels and films can help motivate action. We may also read some earlier narratives of environmental catastrophe, and some nonfictional discussions of climate change. Likely authors include Amitav Ghosh, Margaret Atwood, Barbara Kingsolver, Kim Stanley Robinson, and Richard Powers.

76-750 Critical Theories about Literature

Fall

This course studies the long-debated problem of how readers or spectators respond to texts (in print, performances, film, or painting) from ancient rhetoric and tragedy to contemporary mass culture. We will read in a range of critical theories, from thinkers like Aristotle, Plato, and Longinus to recent theorists in poststructuralism, gender studies, Marxism, and affect theory. How have such critics and theorists thought about the nature of the text and of representation and #8212; or the relation of authorship to reading, ideas, and affects? What techniques of analyzing literary texts have such theories stimulated? Two papers and vigorous in-class discussion will be required.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-754 Watchdog Journalism

Intermittent

The practice of journalism involves covering the news of the day. Investigative journalism uncovers it, digging through public records and data to expose corruption or correct social injustices. The process takes patience and persistence, as well as familiarity with right-to-know laws, to find that gold nugget of information that exposes secrets or becomes the missing piece to a larger puzzle. In this course, students will learn investigative techniques that make the powerful accountable, using government documents, financial filings and databases to spot undetected crime patterns, an unfair housing policy or perhaps questionable spending by a non-profit charity. Investigative journalism has a storied history of exposing wrongdoing and today many of the tools historically used to tell those stories are available to everyone. This course will help budding journalists, researchers and anyone else interested in addressing societal problems find those tools and learn how to use them. This course meets the Dietrich College Deciding Gen Ed requirement.

76-755 Leadership, Dialogue, and Change

Fall

This course offers an alternative to the "great man" theory of leadership and #8212; in which success is built on charisma, power, status, or institutional authority. The contemporary model of "adaptive leadership," however, depends on an ability to draw a divided community into a dialogue that re-frames the problem and may even call on us to re-interpret our values. We will see this in action, comparing the methods of Martin Luther King to the radical community organizing of Saul Alinsky, and in the influential of African-American cultural critiques of Cornel West and bell hooks, and in the work of students calling for change on campuses. All this work poses a question: how does dialogue work in the rhetoric of making a difference? So in the second half, we put theory into practice, organizing a CMU Community Think Tank on a campus issue, in this case on student empowerment will learn strategies for analyzing a problem, framing, issues, giving rhetorical presence to those problems and creating counterpublics that put new ideas into circulation. The class collects data across diverse, often competing perspectives, to create a Briefing Book, that will guide your live Round Table problem-solving dialogues, and then document, write and publish your Findings www.cmu.edu/thinktank. As a portfolio project it will demonstrate your ability to support problem-solving dialogues across difference in a community or organization.

76-758 Rhetoric & Storytelling

Spring

What are stories and why do we tell them? What purpose do they serve? What makes a story true? What effect do stories have on those who hear them? In this course, we will ask how narratives work rhetorically to shape how we perceive and encounter events, movements, places, and experiences. Students can expect to read and discuss narrative theories and practice employing these theories to analyze story artifacts, such as written collections, political speeches, newspaper articles, curated experiences, and oral histories. We will begin the semester by exploring and analyzing the many stories surrounding September 11 but will also consider the stories that infuse recent or local subjects of interest. Students will investigate the effect these and other narratives have on contemporary contexts. Any student who is interested in developing a critical awareness of the rhetorical power of storytelling and enhancing their analytical toolkit will benefit from this course. Most class sessions will involve guided student discussions of theoretical texts as well as collaborative opportunities to analyze story artifacts. Weekly assignments will include short analyses and reflection activities. The course will culminate in a final project where students will select and analyze a collection of stories within a cultural, social, and/or historical context.

76-762 Introduction to Translation

Fall: 9 units

In "Introduction to Translation," we will survey a number of different translation theories in order to understand the various approaches that are at our disposal when translating a text. In addition, we will briefly explore several fields of translation studies, such as health care, business or literature, that require specialized terminology and expertise in the subject. All theory taught in class will be accompanied by hands-on translation projects that will give students the opportunity to try out their knowledge first-hand and evaluate the usefulness of different approaches on a personal basis.

76-763 Translation as Profession I

All Semesters: 3 units

In "Translation as a Profession," we will learn from professionals in the field of translation. Every class will feature a guest speaker from the Pittsburgh area and beyond who will present his or her own educational background, experience in the field and current relation to the translation industry. Students will meet a variety of professionals, learn about the field, and establish valuable connections for the future.

76-765 Translation as a Profession III

All Semesters: 3 units

tbd

76-766 Essay Writing Workshop

Fall

In this course we will analyze the different types of narrative structure, narrative suspense, voice, metaphor, and point of view that make for effective non-fiction writing. We will also examine the difference between good writers and good work, the functions of objective distance from and intimate investment in a subject, as well as the philosophical questions spurred by non-fiction writing. What is the non-fiction writer's role, and how does it differ from that of the fiction writer? Where do the two genres overlap? What gives non-fiction writing integrity? What does the term "creative non-fiction" mean? How have the form and aims of non-fiction writing - from memoir to essays to long-form journalism - evolved for better and for worse? We will scrutinize the writing of Eula Bliss, Kate Fagan, Joan Didion, James Baldwin, Jo An Bear, Gary Younge, David Foster Wallace, Umberto Eco, and many others. In addition to critical writing assignments, students will have several opportunities to write their own non-fiction pieces.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-771 Teamwork for Innovators

Fall

Academic teams, campus organizations, workplaces are all dynamic activity systems, organized and driven by institutional habits and rules, by roles, status and power, and by the material and conceptual tools we draw on. Yet as we have all observed, these Rules, Roles and Tools often operate in contradictory ways, even in conflict with one another. Effective team leaders are able to recognize these contradictions and draw a writing group, a project team, a social organization or a workplace into what is called an "expansive transformation." That is, to innovate new ways of working together. In this course, you will learn how to become more effective not only as a team member, but also a project leader, and even group consultant in your college work and workplace. Looking at films, case studies, research, and your own experience, we will learn how to analyze how teams of all sorts are working, to communicate more effectively across different expectations and values, and to collaboratively innovate new ways of working together. Your final project will let you document your ability to be a knowledgeable team leader and effective collaborator.

76-772 News Writing

Fall: 9 units

In this course, we will study and learn the fundamental skills of journalistic writing as well as discuss topics related to how different media outlets cover news. On the writing side, we will start with the basics - the importance of accuracy, clarity and fairness, writing for audience, striving for objectivity, judging newsworthiness, meeting deadlines. The core class work (and most of your grade) will be based on seven writing assignments due approximately every two weeks throughout the semester. Expect to do some writing each class period. We will learn how to write a story lead, how to structure a story and how to write different kinds of news stories, from crime news to features to editorials and commentary. We also will learn how to research a news story, conduct an interview and sort through mountains of information to discern what's important so we can write about it in a clear, concise manner.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-773 Argument

Fall and Spring

This course introduces the fundamentals of argumentation theory and offers guided practice in analyzing and producing arguments. Through analysis, we will learn what an argument is, how to identify one, and what the names and functions of a variety of argument features are. We will also explore the production of argument by pursuing the questions: What are my argumentative goals? How do I build a theory of my audience? What means of persuasion are available for me to achieve my goals? And how should I order the contents of my argument? To answer these questions, we will explore argument in a variety of genres including visuals, op-eds, presidential speeches, and congressional testimonies.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-784 Race, Nation, and the Enemy

Intermittent

Conflicts over racial and national identity continue to dominate headlines in the United States as they often have during the nation's history, from debates regarding the immigration, naturalization, and birthright citizenship of racial minorities to debates regarding racial disparities in access to civil rights. This course explores the discursive practices through which racial and national identities are formed and the frequent conflicts between them, particularly by focusing on the role of enemies, threats to the nation, and sacrifices made on behalf of the nation in American public discourse. Alongside primary sources of public discourse regarding wars, the immigration and citizenship of racial minorities, racial segregation and civil rights, and the criminal prosecutions of dissidents during periods of crisis, we will read secondary sources offering multiple theoretical and disciplinary approaches to the study of racial and national identity formation. Along with regular brief responses to readings, assignments will include a short rhetorical analysis paper and a longer research paper.

76-786 Language and Culture

Fall

This course is an introduction into the scholarship surrounding the nature of language and the question of how language shapes and is shaped by social, cultural and political contexts. We will begin by studying important literature in linguistics and language theory, both to introduce us to how scholars think about language and to give us a shared vocabulary to use for the rest of the semester. We will then move into case studies and theoretical works exploring the intersections of language use, individual and group identities, and the exercise of power, in its many forms. In particular, we will focus on the relationship between language and culture by asking, in what ways does language influence and constitute social change? How is social change reflected by changes in the way we use language? Over the course of the semester, you will work on applying the knowledge and theoretical tools you gain to your own analysis of a linguistic artifact that you choose.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-787 Writing in the Disciplines

All Semesters

This mini will introduce you to the theory and practice of writing instruction in contexts outside of English studies. We will learn about the distinction between Writing across the Curriculum and Writing in the Disciplines and challenges to providing integrated, high quality writing instruction across the university. We will explore the implications of the wide variety of forms of academic writing for instruction in English classrooms, including high school and first-year writing classrooms. Assessments will include reading responses and a final paper reviewing research on writing in a specific writing context of your choosing. Students enrolled in the course for six units will be expected to do additional readings and give an oral presentation. Please note that in terms of time commitment, a 3-unit mini will require approximately six hours per week (three hours homework and three hours class meetings) and a 6-unit mini will require twelve hours per week.

76-788 Coding for Humanists

Intermittent

This course provides students with the foundational knowledge and skills to develop and/or utilize computer-aided research tools for text analysis. Through a series of hands-on coding exercises, students will explore computation as a means to engage in new questions and expand their thinking about textual artifacts. This course is designed for students with no, or very little, coding experience. So, if you have already taken a programming course, this course is most likely not for you. Students who have taken 15-110 and/or 15-112 may not take this course. For the final project, you will develop a small research project involving a computational analysis of a corpus of texts. You will plan, design, and write a computer program that processes and analyzes a textual corpus of your choice. Students who are taking the course for 9-unit will write a brief project report (3-5 pages) that summarizes your final project. Graduate students in the MA in Rhetoric/PhD programs must register for 12-unit, and will complete a research paper (4,000-5,000 word).

76-789 Rhetorical Grammar

Fall and Spring; 9 units

This is a course in fundamental grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.grammatical structures of English and how these structures fit into the writer's toolkit. This means you will learn a lot about English-language grammar in this course en route to understanding a lot about English language writing. This course is designed for MA students in professional writing and undergraduates who want to improve their grammar, their writing, and their depth of understanding of how improvement in grammar impacts improvement in writing.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-790 Style

All Semesters

This course teaches you how to write clearly. Specifically, the principles you learn in this course will help you 1) to clearly represent actions and the characters responsible for them; 2) to make your paragraphs coherent and cohesive; 3) to write sentences that stress important information; 4) to cut unnecessary prose; and 5) to reshape lengthy sentences so as not to perplex your reader.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-791 Document & Information Design

Spring; 9 units

This course provides students who have already learned the foundation of written communication with an opportunity to develop the ability to analyze and create visual-verbal synergy in printed documents. Students will be introduced to the basic concepts and vocabulary, as well as the practical issues of visual communication design through a series of hands-on projects in various rhetorical situations. Assigned readings will complement the projects in exploring document design from historical, theoretical, and technological perspectives. Class discussions and critiquing are an essential part of this course. Adobe InDesign, Photoshop, and Illustrator will be taught in class, and used to create the assigned projects.

Prerequisite: 76-870

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-793 Narrative & Argument

Spring

This is a course for non-English majors interested in understanding and practicing writing as an art of design thinking and decision-making. We work through seven writing exercises divided into "experiential" and "informational" clusters and we discuss the underlying design principles that unite and divide these clusters. Experiential writing (think character-based fiction, personal profiles, travel writing, narrative histories) supports reader learning but in an indirect, unsupervised fashion. Students write short papers within each of these clusters to glimpse and grapple with the different compositional (design) challenges. Within experiential writing, students practice making themselves (from the first person) and third parties characters readers can come to know and care about. They practice immersing readers within immediate and historical scenes by creating the feel of extended space or elapsed time. Within information writing, students practice presenting readers with new ideas by following the readers' native curiosity (exposition), guiding readers through manual tasks (instruction), and structuring readers' decision-making (argument) in controversies when there are multiple decision paths. Argument is a capstone of information writing that bids for social and political change. While writing for experience and writing for information are distinct clusters, they are highly interactive and the best information writers routinely import techniques of experiential writing into their craft to enliven and layer the reader's experience.

Technologies for making visible for students their tacit decision-making over hundreds and thousands of compositional moves when writing experience and information are introduced and provide students a literal "lens" on the texts they write as an endlessly curious design artifact.

76-796 Non-Profit Message Creation

Intermittent

Non-profit organizations support a multitude of causes ranging from the arts to animals to the environment to health care to human rights to scientific research to many great causes in between. Non-profits achieve their missions by advocating on behalf of their organization's cause, raising public awareness about issues surrounding their cause, and fundraising to make their advocacy possible. In this course, students will select a local, Pittsburgh-area non-profit to examine and produce materials based on the organization's needs. Over the course of the semester students will research the organization's persona and values via interviews with chosen organization's staff and analysis of existing communication channels and different forms of content currently used by the organization. Students will use this research and analyses to inform and shape a final project that should meet the specified, needed deliverables from the selected non-profit. Previous example projects include: Revising a newsletter and specifying future best practices for an organization; developing new format and copy for an organization's website; developing a social media campaign for an upcoming event; developing a grant proposal for an organization's project; among many others. Students will have a wide selection of organizations to choose from and know projects associated with the organization at the beginning of the semester, as these will be organized by the professor. At the end of the course, students will have a portfolio ready material and an increased understanding as to how non-profit organizations advance their causes.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-805 Institutional Studies: English as a Discipline

All Semesters: 6 units

The institution on which this course will focus is the academic discipline, the specific historical form that the production of knowledge in the modern research university has assumed. This course will examine the historical development of the discourses, practices, organs, and associations that have defined English as a discipline. While we will of necessity also look at the theories and values that the discipline has proclaimed at different times, this will not mainly be a course in the history of criticism. Criticism will be considered as one practice among others including philology, literary history, literary theory, rhetoric, and composition. In order to understand the broader context, we will read work by Foucault and others on disciplinaryity. We will also examine allied institutions, including the professions and the university. We will look at the history of university, its funding streams, and its labor conditions and practices.

76-807 Topics in Literary & Cultural Studies

All Semesters

Topics vary by semester. Spring 2022: There Are Black People in the Future. In 2018 the African American artist and CMU professor, Alisha Wormsley created a slogan for a billboard in Pittsburgh's East Liberty that read: THERE ARE BLACK PEOPLE IN THE FUTURE. The billboard had featured many artists and slogans over a period of years, but this one was taken down when the building's landlord objected to the content. The controversy over this piece of art gives this course its name. There are black people in the future, and there are extraordinary black artists in Pittsburgh at this very moment. This special topics course will consider what some are calling a new Pittsburgh Renaissance in the black arts, from art to literature to film and music. Featured writers include Deesha Philyaw, *The Secret Life of Church Ladies*, Brian Broome, *Punch Me Up To The Gods*, and Damon Young, *What Doesn't Kill You Makes You Blacker*. We will also look at the work of the writer Jason England, the artists Alisha Wormsley, Vanessa German, Devan Shimoyama, the rapper Jasiri X, and the film maker Chris Ivey. An in depth look at these artists will be paired with an examination of the history of African Americans in Pittsburgh, and current economics, sociology and politics surrounding race in the city.

76-808 Culture and Globalization

Intermittent

We are often told we live in a period of globalization, but what that means differs widely. Theories of globalization describe such diverse processes as international capital and markets, neo-liberalism and neo-colonialism, environmental devastation, transnational labor and migration, modernity, shifts in spatial and temporal relations, cosmopolitanism, global cultural production and consumption, and the resurgence of nationalism. In this course we will explore and historicize the concept of globalization from both a global literary perspective and an interdisciplinary lens. Pairing literary works from around the world with scholarship from sociology, political science, gender and critical race studies, and anthropology, we will examine the contradictions, conflicts and possibilities of associated changes in the world. We will investigate the role of representation and aesthetics by considering the work of literary writers as well as some filmmakers, journalists and activists. The course will be organized as a series of topical foci that might include neoliberalism and labor, the local and the global, environmental changes, secularism and tradition, the globalization of feminism, and global migration and border control.

76-813 Book Design: A Cultural History

All Semesters: 12 units

Today the book is thriving despite earlier predictions of its "death" at the hands of the digital media. What has made the book so powerful a medium over six centuries? This course will take you into the book's makeup, design, and impact over time. We study how the book was made at different times in its history for instance, the manuscript book (medieval), the hand-press book (Renaissance and eighteenth century), the machine-made book (1800s to present). We also ask how today's databases like Google Books make us see new dimensions of the print medium that were not visible earlier. Likewise we will study theories of the print medium and the cultural effects of the book among readers and social groups. Students will have hands-on experience with a printing press and the Rare Book archives at Hunt and Hillman libraries. Two papers and shorter assignments will be required.

76-818 Rhetoric and the Body

Intermittent

This course offers an introduction to rhetorical studies of the body and is centered on the following three questions: What is the role of the body in rhetorical theory? What role does rhetoric play in constructing the body as a raced, gendered, dis/abled, cultural, fleshy, and political entity? And, how might moving, feeling bodies challenge, regulate, or disrupt these rhetorical constructions and furthermore, our theories of rhetoric? Our readings will explore the role of embodiment in rhetorical theory, examining a number of contemporary and historical theories of the body. In the process, we will explore how to put rhetoric and the body into conversation with one another and what methodological implications this conversation has for rhetorical studies more broadly. The goal of this course is to provide breadth rather than depth, with the assumption that most students, even those relatively familiar with body and/or rhetorical theory, will approach rhetorical studies of the body as novices. Students will conduct their own research on a topic related to rhetorical studies of the body that also aligns with their professional and academic goals. Graduate students interested in research will benefit from this course's focus on theory and the professional genres central to rhetorical studies. Undergraduate students (both majors and non-majors) will have the opportunity to examine how the body intersects with communication and writing contexts in their everyday public and professional lives. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-822 Intro to Gender and Sexuality Studies

Intermittent: 6 units

This graduate-level course offers students a scholarly introduction to theories of gender and sexuality. In this class, we will use intersectional approaches to consider gender theories, feminist theory, masculinity studies, queer theory and scholarly discussions of sexuality. Readings will include Kimberl and #233; Crenshaw, bell hooks, Judith Butler, Raewyn Connell, Sara Ahmed, Eve Sedgwick, and Jasbir Puar, among others.

76-825 Rhetoric, Science, and the Public Sphere

Intermittent

In the 21st century science and technology are ubiquitous presences in our lives. Sometimes these phenomena spark our imagination and affirm our confidence in a better future. In other instances, they create fear and generate protests over the risks new technologies and scientific ideas pose to prevailing social, cultural, economic, and political orders. In this course we will examine the complex dynamics in the relationships between science, technology, and society. Towards this end we will engage with questions such as: How do we decide who an expert is? To what extent do scientists have an obligation to consider the social and ethical consequences of their work? Is public education about science and technology sufficient for addressing social concerns about risk and controversial scientific ideas? We will grapple with these and other questions by exploring public debates including conflicts over global warming, vaccinations, and the AIDS crisis. With the help of analytical theories from sociology, rhetoric, and public policy, we will develop a framework for thinking about argument and the dynamics of the relationship between science, technology, and the public. We will also look to these fields for tools to assess public debate and to complicate and/or affirm prevailing theories about the relationship between science and society.

76-829 Digital Humanities

Intermittent

This course is a "learn by doing" introduction to questions and methods in digital humanities, with special emphases on common tasks in digital history, digital literary studies, library science, and cultural analytics. Students will likely partner with a national humanities organization to tackle real-world humanities problems while developing core computational competencies such as those required for gathering data (text mining, APIs), transforming data (OCR, regular expressions, natural language processing, image magick), file management (shell commands), data visualization (matplotlib, arcGIS), and more.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-831 Gender Play in Early Modern Drama

All Semesters: 12 units

The playhouses of early modern London offered access to an astonishing spectacle that would be difficult to find anywhere else in the city: men dressed as women, skillfully reproducing (but also exposing, interrogating, and refining) the significations that structure concepts of gender difference. In addition to this fundamental condition of performance and theatrical experience, the plots of the plays themselves regularly engaged with issues pertaining to gender and sexuality, an interest that runs through the raunchy satires performed by companies of adolescent boys, the innumerable comedies of cross-dressing and mistaken identity, and the equally numerous tragedies centered on problems of inequality and imbalances of power. This course will consider a wide range of drama from the period alongside a selection of readings in sexuality and gender theory, thus bringing early modern dramatists such as William Shakespeare and Thomas Middleton into conversation with contemporary thinkers such as Judith Butler and Sarah Ahmed. The body of core texts will include *Twelfth Night*, *The Merchant of Venice*, *As You Like It*, *The Roaring Girl*, *The Taming of the Shrew*, *The Tamer Tamed*, *The Island Princess*, *The Witch of Edmonton*, *The Silent Woman*, *Women Beware Women*, and *Galatea*.

76-833 Historicisms

All Semesters

What is a critical historicism? What theories of history, texts, and social life have been driving literary and cultural scholarship since the late twentieth century? What is the ongoing tension between historical accounts of literature/culture? This course will introduce students to ways of thinking about how literary and cultural texts or genres can be studied historically, whether they were written in the early modern age or the twentieth century. We will especially explore controversies about methods of studying texts in history and #8212; about historicism vs. presentism, the relation of text and context, periodization, *longue dur* and #233;e, reception history, transhistorical meanings. Readings will include Walter Benjamin, Karl Marx, Michel Foucault, Jack Halberstam, Stephen Greenblatt, Judith Newton, Joan Scott and others.

76-844 History of Books and Reading

Fall

Rather than putting an end to the book, digital media have had the oddly exhilarating effect of making us look at all kinds of print, past and present, through newly focused lenses. This course will introduce you to the history of books and reading, a cross-fertilizing field of study that is having an impact on many disciplines, from the history of science to literary history, cultural studies, and the arts. Scholarship in this still-emerging field will include work by Roger Chartier, Michel Foucault, Elizabeth Eisenstein, Pierre Bourdieu, Michel de Certeau, and the current scholars who appear in one of our key books, "Interacting with Print: A Multigraph." We'll also read primary texts by Joseph Addison, Jane Austen, Samuel Coleridge, and Wilkie Collins to see how differing modes of print and reading became highly contested cultural and political matters in the eighteenth and nineteenth centuries. Other topics include the division between new reading publics and their ways of reading books; important changes in book production, typography, printing methods (hand-press to steam press). Such knowledge of the history of print has become especially crucial in an era of emerging "new media" and the field of digital humanities in the university. Two papers will be required on shorter paper (5-7 pp.) and a longer research paper on the uses of books and print by producers and readers. Though the course meets in Baker Hall, you will have hands-on experience with early books and other forms of print as we also meet periodically in the Rare Book Room at Hunt Library.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-846 Revenge Tragedy

All Semesters

Attendants to the early modern English theater seem to have had an almost insatiable appetite for revenge tragedy: a lurid, blood-soaked genre distinguished by plots involving insanity, skulls, ghosts, poisonings, stabbings, suicide, and other forms of unnatural death. This course will cover key examples of the genre, putting particular emphasis on the depiction and interrogation of justice, analyses of death, and playful engagement with theatricality. Our central curriculum will include the following plays: *Thyestes* (Seneca), *The Spanish Tragedy* (Kyd), *Titus Andronicus* (Shakespeare), *Hamlet* (Shakespeare), *The Revenger's Tragedy* (Middleton), and *The Duchess of Malfi* (Webster). We will also read a selection of critical essays and related literature from the period.

76-849 Race and Media

Intermittent

This course will introduce students to useful methodological approaches to analyze race and representation within a variety of media formats. Media in this course is understood broadly: technologies used to store and deliver information. With this rather broad understanding in mind our course will look at how artists and intellectuals use discrete formats (print, film/video, electronic, and other recording mediums) to imagine, remediate and study the circulation of racialized bodies and identities within global capitalism. We will also think about the concept of race itself as another, particularly problematic "media" format used to store and deliver information about the human for political, economic, ideological and juridical purposes. The class will be organized around specific material and "immaterial" media objects that will allow us to explore the processes of (re)mediation that characterize racialized bodies and formats. We will look at a range of formats from literature and music to film, television, and social media. The course is structured to provide both a chronological and historicist approach to the discourses that define race and media. More than likely, we will watch and (or) read the works of D.W. Griffith, Nella Larson, Melvin Van Peebles, Lizzie Borden, Audre Lorde, Claudia Rankine, Alex Rivera and Nia DaCosta. We will also read the theoretical works of Jacques Ranciere, Huey P. Newton, Dallas Smythe, Lisa Gitelman and Michael Gillespie, Simone Browne, Theodore Adorno, Sara Ahmed and many others.

76-850 Law, Culture, and the Humanities

Intermittent

"I'm not a lawyer, but..." How many times have you heard this disclaimer, closely followed by a lay analysis of law? This course, an introduction to the cultural study of law for graduate students and advanced undergraduate students, can be seen as an introduction to what goes into the making of such a statement. Where do we get our ideas about law? What do we mean when we say "law"? What counts as law? How does culture influence law, and law, culture? And to what degree should historical context condition any answers we might be tempted to give? Students in the course will study works in a range of genres (novels, plays, poems, judicial opinions, pamphlets) and develop methods for investigating ways that law and culture have been made by one another from the 16th-century to the present. Readings will include influential theoretical accounts of law (Aristotle, Hobbes, Cover, Habermas, Bordieu, MacKinnon, Alexander), canonical texts in Law and Literature (Shakespeare's Measure for Measure, Melville's *Billy Budd*, Kafka's *The Trial*) and some "weird fiction" by the novelist/legal theorist China Mi and #233;ville. As a counterpoint to the fiercely anti-historical "law and economics" movement, however, the course will put special emphasis on rooting intersections of law and culture in rich historical context, considering both local and international legal contexts (sometimes in fairly technical detail) alongside so-called "ephemera" of culture. Students will tackle the especially fruitful "case" of Renaissance Britain before developing final research projects, whether on the Renaissance or another period of their choosing.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-852 Generations and Culture

Intermittent

We frequently hear about generations and #8212;the Millennials and their multitasking, Gen X and their minivans, and the Baby Boomers and their self-satisfaction and #8212;but generations have usually been ignored in cultural studies. Yet generations have significant impact on cultural tastes, consumer choices, and political views, as a good deal of research shows, and identity, alongside other factors such as race, class, gender, sexuality, ethnicity, and abledness. This course will study the theory of generations, as well as novels and films that tell us about generations.

76-853 Literature of Empire

Fall

Nineteenth and early twentieth-century British literature was shaped by events taking place outside as well as inside of national borders. Even in the eighteenth and nineteenth centuries, with international trade and slavery supporting the manor house and plantations abroad providing the cotton for British looms, the "England" of English literature spanned the globe. By the first half of the twentieth century, this empire had begun to collapse in upon itself, a process witnessed by writers inside Britain and its colonies. This course will investigate British literature within the international context of global imperialism. A section on gothic stories takes us into the realm of popular culture with Mary Shelley's *Frankenstein* and Arthur Conan Doyle's short stories. We take to the seas with Joseph Conrad's *Lord Jim*, before we consider W. Somerset Maugham's exploration of sexuality in the tropics in *The Painted Veil*. Finally, we return to England to outline the links between colonial empire and international war rendered in Virginia Woolf's *Mrs. Dalloway*. These literary works will be read alongside some of the most important works of postcolonial theory. While course readings focus on 19th and early 20th century, student's will undertake a research project over the semester in their own period of interest in British literature in connection with empire studies.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>

76-854 Introduction to Literary and Cultural Studies

Fall

"Cultural studies" covers a wide umbrella of practices. In this course, we will try to get a clearer sense of it by looking at its history, particularly in the UK and the US from the 1960s to the present. We will read pioneers in the formation of British cultural studies, such as Stuart Hall and Hazel Carby, French theorists such as Louis Althusser and Michel Foucault, and influential contemporary theorists such as Edward Said and Judith Butler. In addition, we will look at those forging recent initiatives such as affect theory (Sianne Ngai), queer theory (Jack Halberstam), afro-futurism (Alondra Nelson), distant reading (Franco Moretti), and environmental humanities (Rob Nixon). Throughout, we will think about the way that cultural studies might provide alternative methods for doing criticism, and you will write several papers and develop your own research project.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-864 Creative Nonfiction Workshop

Fall

This course will deepen your understanding of the possibilities for writers engaged with the genre of Creative Non-Fiction. We'll be reading books and essays from a variety of writers, including CMU graduate Neema Avashia, whose collected book of essays has been recently published. We'll read essays and memoir that illumine the formation of identity, that question the status quo, that celebrate human connection, and that often shine a light on injustices shaping our world. Students will write their own essays and memoir, and class will be conducted as a discussion where all will be expected to show up regularly, and remain engaged so as to create a place where students get to know one another and support each other as writers.

76-867 Crime Fiction and Film

Intermittent: 12 units

This course will be concerned with hardboiled crime fiction in print and on screen. The hardboiled emerges in Ernest Hemingway a distinctive literary style, and about same becomes a formula for pulp crime fiction. The language and attitude of the hardboiled became associated with urban gangsters in films such as *The Public Enemy*. Newspaper crime coverage beginning in the 1920s becomes increasingly frank in both its language and photographic coverage of crime. These various elements will be the material for a new kind of literature represented Dashiell Hammett, James M. Cain, and especially Raymond Chandler, and for a cycle of films that owe much to their work, film noir. Chandler was responsible for invention of one of most enduring types in American fiction, the hardboiled detective. The course will focus on Chandler and the crime stories after him that make various uses of that type and the formula that has become associated with it. Throughout the course we will consider the social and political contexts in which these cultural forms developed, and what cultural work the hard-boiled performed. We will be especially interested such questions as the function of the misogyny typical of much of it, the different representations of race by white and black artists, the representation of police, whether the hardboiled is best understood as having a working-class affiliation, and the degree to which its various manifestations might be called realist.

76-868 Space and Mobilities

Intermittent

This course will investigate space and movement as social constructions. Space is something dynamically created that may be interpreted for the ways it creates meaning, while movement reproduces and constitutes power and institutions. This interdisciplinary course considers theories of space and movement as a field of study and in reference to literary and film texts. The course might include discussions of migrants and state borders, cultural constructions of transport, the poetics of space, and the dynamic mapping of the city through movement and sound. Readings might include Henri Lefebvre, Doreen Massey, Edward Soja, Gaston Bachelard, Wendy Brown, John Urry, Tim Cresswell, Marian Aguiar; literary texts might include Brian Friels Translations, Christina Garcia's *Dreaming in Cuban*, W.G. Sebald's *Austerlitz* and Teju Cole's *Open City*. Please note: Freshmen are prohibited from registering for this course. Sophomores must obtain instructor permission. Students across disciplines are encouraged and may work on a final project related to their primary field.

76-870 Professional and Technical Writing

Fall

This course is an introduction to the theory, research, and practice of professional and technical communication as a discipline. Through readings, discussions, projects, and writing workshops, you will develop a rhetorically-grounded approach to analyzing communications problems and producing a range of effective and situation-specific professional documents. This user-centered approach views professional documents as means to accomplish specific, well-defined purposes: getting funding or support for a project (proposals), supporting managerial decision-making (reports), communicating effectively within organizations (email, correspondence), guiding action (instructional writing), getting a job or internship (resumes and application letters), or making choices among various medical treatments (science writing for general audiences). Because writers need a range of skills that go well beyond the actual inscribing of words on a page, you also gain practice in how to test documents on actual users, edit and revise your own work and that of other writers, and participate in and manage collaborative writing projects. The course features three major writing assignments. Core course for MAPW students.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

76-881 Introduction to Multimedia Design

Fall: 12 units

There is increasing demand for professional/technical writers who understand multimedia and its communicative possibilities. This class will provide students with the opportunity to develop the ability to create and analyze multimedia experiences that merge text, spoken voice, music, animation and video. Students will be introduced to the basic concepts and vocabulary of motion graphics, as well as the practical issues surrounding multimedia design and digital storytelling through a series of hands-on projects involving various contexts. Students will explore what it means to write for a dynamic medium and how to take advantage of elements of time, motion and sound to help expand their visual communicative skills. The essentials of Adobe After Effects will be taught in order to build the skills necessary to complete assignments, explore multimedia possibilities and foster each student's unique creative voice. Adobe Premiere and Audition will be employed to support specific tasks. Students will also be taught to capture their own original images, video and narration audio to craft the elements of their projects. It is helpful to have some prior basic experience with Photoshop or Illustrator. In-class discussions, 2 group workshops and critiques are an essential part of this course.

Prerequisites: 76-391 or 51-262 or 76-791

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)**76-884 Discourse Analysis**

Fall

This course teaches an empirical and systematic approach to analyzing texts. The central question we ask is this: how does language shape contexts and how do contexts, in turn, shape language? We typically focus on micro-linguistic elements, but also examine visual aspects of texts.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)**76-885 The New Public Sphere**

Fall

Public deliberation about issues that matter to us is at the heart of the rhetorical tradition. But is meaningful public dialogue really a live option in a divisive, media-saturated world of sound bites addressed to partisan publics? Moreover, is the process of debate, deliberation, and decision making (in which the best argument wins) really the normal (or even ideal) model? Or can people use local public spaces to develop new, more inclusive positions? How might such a process create a boundary-crossing public in which diverse groups enter intercultural deliberation around racial, social, economic or environmental issues? This course looks at critical ways people use rhetoric to take literate social action within local publics. From the debate spurred by Habermas's canonical version of the public sphere, we move to a feminist "rereading" of the Greek Sophists, to more contemporary studies of deliberation in workplaces, web forums, grassroots groups, new media, and community think tanks. Working as a rhetorical consultant into the meaning making process of a local public of your choice, you will also learn how to support your inquiry with a variety of methods, from an interactive activity analysis to a more focused probe into the social/cognitive negotiation conflict may require.

Course Website: <http://www.cmu.edu/hss/english/courses/courses.html>**76-891 Rhetorical Analysis**

Fall and Spring

Students in this course will learn various approaches to analyzing discourse artifacts from a rhetorical point of view. Early in the course, students will identify an artifact or artifacts they wish to analyze. From there, students will be encouraged to explore their own methods of analysis based on two required books for the course and reviews of literature. For the midterm, students will create an annotated bibliography of five specimens of criticism taken from a single journal. For the final project student will first present and then hand in a polished 15 page piece of criticism based on one or some combination of methods. The presentation and final paper count 50% of the grade, with the mid-term, class attendance, participation, and homework making up the final 25%.

76-893 Introduction to Global & Postcolonial Studies

Intermittent: 6 units

Since the 1978 publication of Edward Said's groundbreaking work *Orientalism*, postcolonial theory has gained currency as a critical discourse examining global experiences of colonization and decolonization. Since the term "postcolonial" was first invoked to describe the cultural effects of colonization, the field of study has expanded considerably. Today postcolonial studies looks backwards at earlier works on nationalism and cultural identity, gazes forwards towards seemingly dire futures, and unpacks present conjunctures. In this course, we will follow several threads of postcolonial theory to talk about the discursive operations of empire, the politics of representations, the problems of nationalism, the intersections of race, gender and sexuality in a global context, and the effects of colonialism, imperialism and globalization on economies, ecology, climate, and migration.

76-894 Digital Humanities

Intermittent: 6 units

Digital Humanities is an emerging discipline as well as a broad collection of scholarly activities that apply new technologies to humanities research while expanding traditional forms of scholarly communication. Some of its many facets include: book history, cartography (using maps to better understand the cultural production of texts), the preservation and sharing of collections that are otherwise difficult to access. DH can also include the fostering of new creative expression by using digital media. In this mini we'll be reading a variety of leaders in the field including Robert Binkley, Franco Moretti, Matthew Jockers, Peter deBolla, Johanna Drucker, Alan Liu, Jerome McGann, Christopher Warren, and Bethany Nowviskie, attending the CMU DH lunch workshops, and taking some field trips around the city to see some DH projects in action.

76-896 Research Methods in Rhetoric & Writing Studies

All Semesters

This course is a survey introduction to historical, empirical, text-based, and qualitative methods of inquiry used in the fields of rhetorical and writing studies. We will read broadly to understand the philosophical questions, research traditions, practical applications, and innovative directions that shape the field, exposing students to a range of methods and methodologies. Studies of rhetoric, writing, and literacy have evolved tremendously, and we will examine approaches for how to trace, analyze, and critique the use of meaning making in a variety of cultural, political, workplace, technological, and pedagogical contexts. By the end of the course, students will develop a sense of how to put together an effective research project on their own and design and articulate the research methods and methodologies appropriate to that study. Throughout, we will ask a fundamental question: How do rhetoric, writing, and literacy work and for what consequences?

76-898 Marxisms

Intermittent: 6 units

This course is meant to introduce students to basic problems in Marxist theory, among them value and labor, mode of production, base and superstructure, and historical materialism. However, because our particular disciplinary interests, the course will focus on problems of ideology, including hegemony, culture, and the subject. Readings begin with works of Marx and Engels, including selections from *The Economic and Philosophic Manuscripts*, *Capital*, Vol. 1, and *The German Ideology*, and move on to other contributors including Luk and #225;cs, Gramsci, and Althusser. We look at Raymond Williams and Stuart Hall as examples of Marxism in the specific context of cultural studies.

Course Website: <http://www.cmu.edu/dietrich/english/index.html> (<http://www.cmu.edu/dietrich/english/>)

Department of History

Nico Slate, Department Head
 Location: Baker Hall 240
 Phone: 412-268-2880
 Fax: 412-268-1019
www.cmu.edu/dietrich/history (<http://www.cmu.edu/dietrich/history/>)

Undergraduate Degree Options in the Department of History

The B.A./B.S. in Social & Political History

The B.A. in Global Studies

The B.A./B.S. in Ethics, History, and Public Policy

The Department of History offers undergraduates a choice of three majors: Social & Political History, Global Studies, and Ethics, History, and Public Policy. Specific requirements and courses for each major are detailed below.

All three History majors are grounded firmly in the liberal arts. Each has a strong interdisciplinary bent and an equally strong commitment to using knowledge of the past to illuminate present-day social, cultural, and political affairs.

In different ways, all three majors emphasize empirical research methods and conceptual analysis, and cultivate reading, research, and writing abilities central to a variety of professions. Our students develop strong analytic and writing skills; choose among diverse U.S., global, and thematic courses; learn experientially through internships and/or study abroad; and benefit from small class sizes and easy access to faculty who are internationally known for innovative historical, anthropological, and other social science approaches to investigating the past. The study of history necessarily includes diverse societies and controversial public policy issues, usefully blending liberal education with professional development.

History is also excellent preparation for leadership positions in law, business, journalism, politics, education, and government service (e.g., U.S. Foreign Service, Health & Human Services, Federal Trade Commission). The resumes of innumerable CEOs and government statesmen show how effectively the study of history serves as a foundation for preparing leaders both at home and abroad.

Having been trained to analyze subtle and complex issues, to develop breadth of understanding, to dig out information and make sense of it, and to present their findings effectively, graduates of the History Department do extremely well in many types of for-profit, non-profit, governmental, and non-governmental organizations. Because history training combines research and writing skills with analysis of social and policy trends, it also prepares graduates for journalism and other writing careers in the modern media age.

All three History degree programs combine easily with majors in Business, Economics, English, Information Systems, Modern Languages, Philosophy, Professional Writing, Social and Decision Sciences, and Statistics.

Additional Majors

The majors in Social & Political History, Global Studies, and Ethics, History, and Public Policy may be declared as additional majors in consultation with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra. You can reach Dr. Garnhart-Bushakra in the History Department, Baker Hall 240 to schedule a meeting with her directly.

Interdepartmental Majors

In addition to the Ethics, History, and Public Policy major, History faculty are also integral participants in three interdepartmental majors described elsewhere in this catalog: International Relations and Politics in the Institute for Politics and Strategy, Arabic Studies, and Russian Studies in the Modern Languages Department.

Minors

Options for pursuing a minor in Social & Political History or Anthropology are discussed below, following the sub-section on Ethics, History, and Public Policy.

Several other minors with strong History content, detailed elsewhere in the Undergraduate Catalog, can be linked with any degree. Students should contact the relevant History faculty members listed below:

- African and African American Studies: Professor Edda Fields-Black (fieldsblack@cmu.edu)
- Environmental and Sustainability Studies: Professor Abigail E. Owen (aeown@cmu.edu)
- Gender Studies: Professor Lisa M. Tetrault (tetrault@andrew.cmu.edu)
- Religious Studies: Professor Allyson F. Creasman (allysonc@andrew.cmu.edu)
- Russian Studies: Professor Wendy Goldman (goldman@andrew.cmu.edu), Professor Tatyana Gershkovich (tgershko@andrew.cmu.edu)
- Science, Technology, and Society: Professor Christopher J. Phillips (cjp1@cmu.edu)

Research and Outreach Centers

History Department faculty members lead three research and outreach centers that advance new interdisciplinary knowledge and help translate knowledge into public policies that further the pursuit of social, economic, and political justice.

1. CAUSE (Center for African American Urban Studies and the Economy), Joe W. Trotter, Director
2. The Bajaj [India] Rural Development Lab, Nico Slate, Director
3. The Center for Human Rights Science, Jay D. Aronson, Director

The Major in Social & Political History (SPH)

Professor Ricky Law, *Director of Social & Political History and Director of Undergraduate Studies*, History Department
 Location: Baker Hall 238B, 412-268-2880
rlaw@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
 Location: Baker Hall 240, 412-268-2880

www.cmu.edu/dietrich/history/undergraduate/sph (<https://www.cmu.edu/dietrich/history/undergraduate/sph/>)

Social & Political History (SPH) is a research- and writing-intensive major that emphasizes analysis of change over time and in-depth understanding of the societies, cultures, economies, political systems and conflicts that have shaped our world. History electives focus on areas of faculty expertise such as science, technology, race, culture, public health, environment, gender, labor, war, politics, sports, education, and criminal justice.

All majors take Introduction to Historical Research & Writing (79-200, 9 units) and the capstone Historical Research Seminar (79-420, 12 units), where they conduct individualized projects using archival and other primary sources. Several students have published the results of their research, and we are exploring new ways to facilitate future publication of students' research in both undergraduate and professional history journals.

The broad analytic, research, and writing skills cultivated by the SPH major prepare students for success in a wide variety of graduate and professional schools, and for exercising leadership in careers in business, law, government, education, journalism, public policy, social work, the armed services, Foreign Service, media, museums and libraries. Often, history graduates pursue post-undergraduate professional school, such as law, business administration, education, public policy, urban planning, librarianship, journalism, the ministry, and social work.

For students interested in pursuing a professional career in History, options today include not only research and teaching -- our graduates have earned Ph.D. degrees at Harvard, Northwestern, and other major universities -- but also expert positions as historians in museums, archives, historic sites, the armed services, media outlets, and other public history venues.

Students graduating with a primary major in Social & Political History may pursue a B.A. or B.S. degree. SPH may also be taken as an additional (i.e., second) major.

Curriculum (93 units)

All students in the Social & Political History major are required to complete two research-training courses: Introduction to Historical Research & Writing

(79-200, 9 units), and Historical Research Seminar (79-420, 12 units), which is regularly offered in the Fall semester of the senior year. Students must earn a final grade of "C" or better in these two courses in order to fulfill the requirements for the *SPH* major.

Students in the Social & Political History major are also required to take at least one of the following general education courses: Genocide and Weapons of Mass Destruction (79-145, 9 units) or Democracy and History: Thinking Beyond the Self (79-189, 9 units).

In addition, students must take two historical *survey courses* from a wide range of attractive options that include most major regions of the world.

Otherwise, students enjoy great flexibility: they are free to take additional survey courses or to specialize in thematic topics or regions of the world that are of special interest to them.

If you are interested in pursuing a minor in SPH, please view the section (see below) for the Minor in Social and Political History.

Social & Political History Major (*SPH*)

I. Required General Education Course (9 units)

| | | |
|--------|---|---|
| 79-145 | Genocide and Weapons of Mass Destruction | 9 |
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |

II. Required History Department Courses (21 units)

| | | |
|--------|---|----|
| 79-200 | Introduction to Historical Research & Writing | 9 |
| 79-420 | Historical Research Seminar | 12 |

III. Required Survey Courses (*choose two* -- 18 units)

| | | |
|--------|---|---|
| 79-160 | Introduction to the History of Science | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-204 | American Environmental History | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-206 | Crime and Punishment in Early Modern Europe | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-224 | Mayan America | 9 |
| 79-225 | West African History in Film | 9 |
| 79-226 | African History: Earliest Times to 1780 | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-249 | 20th Century U.S. History | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-260 | Nazi Germany | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-269 | Russian History: From Socialism to Capitalism | 9 |
| 79-272 | Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal | 9 |
| 79-282 | Europe and the World Since 1800 | 9 |

| | | |
|--------|---|---|
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-320 | Women, Politics, and Protest | 9 |

IV. Social & Political History Elective Courses (45 units)

Students must complete 45 elective History units (*typically 5 courses*) for the Social & Political History major. Any History Department courses not fulfilling another major requirement may be chosen as an elective.

Social & Political History majors have considerable flexibility in choosing their elective courses, but should consult with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240, in making their selections.

For a complete list of elective course options in History, please consult the History course descriptions elsewhere in this catalog. The selections below are designed to give you a sense of the great variety of thematically centered courses (in addition to the survey courses listed earlier) that History Faculty members regularly teach:

| | | |
|--------|---|---|
| 79-170 | Introduction to Science, Technology, and Society | 9 |
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-201 | Introduction to Anthropology | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-216 | Genghis Khan and the Mongol Empire | 3 |
| 79-218 | Tiananmen Square and Popular Protest in Modern China | 6 |
| 79-219 | Hong Kong, Taiwan and the Idea of "China" | 6 |
| 79-220 | Screening Mexico: Mexican Cinema, 1898 to Present | 6 |
| 79-222 | China and the Second World War | 6 |
| 79-234 | Technology and Society | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-243 | The Civil War in American Memory | 6 |
| 79-246 | Industrial America | 9 |
| 79-247 | African Americans, Imprisonment, and the Carceral State | 9 |
| 79-252 | "Harriet": Harriet Tubman, Slavery, and the Underground Railroad | 6 |
| 79-257 | Germany and the Second World War | 9 |
| 79-256 | Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990 | 9 |
| 79-260 | Nazi Germany | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-268 | World War I: The Twentieth Century's First Catastrophe | 9 |
| 79-270 | Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present | 9 |
| 79-273 | Jews and Muslims in History | 9 |
| 79-276 | Beyond the Border | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-289 | Animal Planet: An Environmental History of People and Animals | 9 |
| 79-290 | The Slave Passage: From West Africa to the Americas | 9 |
| 79-297 | Technology and Work | 9 |
| 79-298 | Guns, Gun Cultures, and Gun Violence in American History | 6 |
| 79-300 | History of American Public Policy | 9 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 79-303 | Pittsburgh and the Transformation of Modern Urban America | 6 |
| 79-304 | African Americans in Pittsburgh | 6 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |

| | | |
|--------|--|---|
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |
| 79-316 | Photography, the First 100 Years, 1839-1939 | 9 |
| 79-317 | Art, Anthropology, and Empire | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-319 | India Through Film | 6 |
| 79-322 | Stalin and the Great Terror | 9 |
| 79-324 | #MeToo: Naming and Resisting Gender Violence | 6 |
| 79-326 | Shall We Dance? Culture, Politics, and Movement in the 20th Century | 6 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-337 | Educational Policy and "School Choice": Historical and Contemporary Perspectives | 6 |
| 79-338 | History of Education in America | 9 |
| 79-339 | Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961) | 6 |
| 79-340 | Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08) | 6 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-345 | Roots of Rock & Roll | 9 |
| 79-346 | American Political Humor | 9 |
| 79-350 | Early Christianity | 9 |
| 79-352 | Christianity Divided: The Protestant and Catholic Reformations, 1450-1650 | 9 |
| 79-357 | Science and the Body | 6 |
| 79-359 | Truth, Lies, and Propaganda: A Historical Inquiry | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 79-363 | The Rise of Modern Golf, 1860 to the Present | 6 |
| 79-368 | Un-natural Disasters: Societies and Environmental Hazards in Global Perspective | 6 |
| 79-371 | African American Urban History | 9 |
| 79-372 | The Rise and Fall of Pittsburgh Steel | 6 |
| 79-373 | Culture and Revolution: The Socialist Experiment in Soviet Russia | 6 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |
| 79-383 | The History of Capitalism | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 79-387 | General Francisco Franco: Fascism and its Legacies in Spain | 6 |
| 79-394 | Exploring History through Geography | 6 |
| 79-395 | The Arts in Pittsburgh | 9 |

Social & Political History Major — Sample Curriculum

| First-Year | | Second-Year | |
|--|----------------------------|--------------------------|--------------------------|
| Fall | Spring | Fall | Spring |
| 79-145 Genocide and Weapons of Mass Destruction or 79-189, Democracy and History: Thinking Beyond the Self | SPH Survey Course | SPH Survey Course | SPH Elective Course |
| First-Year Writing Requirement | 36-200 Reasoning with Data | General Education Course | General Education Course |
| Grand Challenge Seminar | General Education Course | General Education Course | Third Course (open) |
| General Education Course | Fourth Course (open) | Fourth Course (open) | Fourth Course (open) |
| General Education Course | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |
| 99-101 Computing @ Carnegie Mellon | | | |

| Third-Year | | Fourth-Year | |
|--|--------------------------|------------------------------------|----------------------|
| Fall | Spring | Fall | Spring |
| 79-200 Introduction to Historical Research & Writing | SPH Elective Course | 79-420 Historical Research Seminar | SPH Elective Course |
| SPH Elective Course | SPH Elective Course | Second Course (open) | Second Course (open) |
| General Education Course | General Education Course | Third Course (open) | Third Course (open) |
| General Education Course | Fourth Course (open) | Fourth Course (open) | Fourth Course (open) |
| Fifth Course (open) | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |

The table above represents a four-year plan for completing all requirements for the Social & Political History Major. Students may declare the major and begin course requirements as early as the start of the sophomore year and in some instances in the freshman year. Students should meet with the department's Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, Department of History, Baker Hall 240, for both short- and long-term course planning.

*Some Social & Political History majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

V. Courses in Other Departments that Satisfy SPH Elective Requirements (up to 27 units)

Students may satisfy the elective requirements in SPH with up to 27 units of the following courses offered by other departments in Dietrich College:

| | | |
|--------|---|---|
| 73-476 | American Economic History | 9 |
| 76-230 | Literature & Culture in the 19th Century | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-295 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 76-449 | Race and Media | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 82-208 | Eastern Europe: Society and Culture | 9 |
| 82-245 | New Directions in Hispanic Studies | 9 |
| 82-247 | US Latinos Literature | 9 |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 82-327 | The Emergence of the German Speaking World | 9 |
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-386 | The Privatization of Force | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 85-380 | In Search of Mind: The History of Psychology | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

VI. 79-505: SPH Internship (6-9 units)

The Social & Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or in areas of policy research that complement their historical interests (as, for example, in a government agency or non-profit organization). The Academic Program Manager will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. Please note, however, that internship credits do not count toward fulfillment of course requirements for the SPH major (though the units do count toward graduation).

VII. Additional Major in Social & Political History (SPH)

The Social & Political History Major may be scheduled as an additional major in consultation with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240.

VIII. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240, to accept equivalent courses as substitutions.

| | | |
|-----------|--|----|
| 21-257 | Models and Methods for Optimization | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 70-208 | Regression Analysis | |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 70-257 | Optimization for Business | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-251 | Empirical Research Methods | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

The Major in Global Studies

Professor Emanuela Grama, *Director of Global Studies*, History Department
Location: Baker Hall 239B, 412-268-3285
egrama@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

www.cmu.edu/hss/globalstudies (<https://www.cmu.edu/hss/globalstudies/>)

The B.A. in Global Studies is an interdepartmental major designed for students interested in humanistic approaches to past and present processes of globalization. The rigorous yet flexible Global Studies curriculum combines courses in anthropology, history, cultural studies, and language training that enable students to gain a nuanced understanding of both global processes and regional histories and cultures. Graduates of the program have pursued careers in a wide range of fields, including law, the private and non-governmental sectors, and graduate work in psychology, business, health and medicine, and international studies.

Faculty affiliated with the program come from the departments of History, Modern Languages, English, and Philosophy, and draw on their international expertise to help students gain a rich, multidisciplinary understanding of global issues and concerns (such as, climate change and the environment; migration; social and political movements; imperial legacies and contemporary politics; art, language, culture, and globalization.)

Students should consult with the Global Studies Academic Program Manager about new courses and study abroad courses that may be approved for the Global Studies major.

Global Studies may be elected as a **primary** or an **additional** major; the requirements for each are the same.

Curriculum

(102 units plus completion of language requirement)

There are three required courses for the major: Introduction to Global Studies (79-275), Global Studies Research Seminar (79-400) and one of the following general education courses: Introduction to Anthropology (79-201, 9 units), Genocide and Weapons of Mass Destruction (79-145, 9 units) or Democracy and History: Thinking Beyond the Self (79-189, 9 units). In addition to these three courses, majors must also complete 72 units of electives and demonstrate proficiency in a modern language other than English. Students may double count a maximum of four courses taken for the Global Studies major that are also being used to fulfill the requirements of other majors and programs. Students should consult with the Global Studies Academic Program Manager about new courses and study abroad courses that may be approved for students pursuing the major in Global Studies.

I. Required General Education Course (9 units)

| | | |
|--------|--|---|
| 79-201 | Introduction to Anthropology | 9 |
| 79-145 | Genocide and Weapons of Mass Destruction | 9 |

| | | |
|--------|---|---|
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
|--------|---|---|

II. Global Studies Introductory Course (9 units)

Students must earn a final grade of "C" or better for the course to count toward the major.

| | | |
|--------|--------------------------------|---|
| 79-275 | Introduction to Global Studies | 9 |
|--------|--------------------------------|---|

III. Language Requirement

Gaining skills in more languages is a crucial component of the major in Global Studies. Students will pursue **at least three semesters of language study**, no matter the level. That is, students could take three introductory courses in three different languages, or three different level courses in the same language, or two different level courses in Language 1 and a third course in Language 2.

If students already know a language at an advanced level, they will take a test to certify those language skills. If they pass the test, they will need to take at least two semesters of language study, focused on a language different from the one they were tested on.

Please see the Modern Languages section of the schedule of classes.

IV. Theoretical and Topical Core Courses (18 units)

To gain a solid foundation in the theories and analytical topics underpinning the B.A. in Global Studies, students select 18 units (typically two courses). Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

| | | |
|--------|---|---|
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-289 | Animal Planet: An Environmental History of People and Animals | 9 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |
| 79-317 | Art, Anthropology, and Empire | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |
| 79-383 | The History of Capitalism | 9 |

V. Transnational, Global, and Regional Courses (27 units)

To gain insight into how complex transnational and global processes shape and are affected by local, national, and regional dynamics, students will select 27 units (typically three courses).

Transnational and Global Courses

| | | |
|--------|--|---|
| 76-337 | Intersectional Feminism | 9 |
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 79-149 | Ancient Rome: What Have the Romans Ever Done for Us? | 9 |
| 79-224 | Mayan America | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-273 | Jews and Muslims in History | 9 |
| 79-270 | Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present | 9 |
| 79-276 | Beyond the Border | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-282 | Europe and the World Since 1800 | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |

| | | |
|--------|---|---|
| 79-333 | African Americans, Race, and the Fight for Reparations | 9 |
| 79-350 | Early Christianity | 9 |
| 79-368 | Un-natural Disasters: Societies and Environmental Hazards in Global Perspective | 6 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 79-510 | Global Studies Guided Reading | 3 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |
| 82-345 | Introduction to Hispanic Literary and Cultural Studies | 9 |
| 84-226 | International Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-389 | Terrorism and Insurgency | 9 |

Regional Courses

| | | |
|--|---|---|
| Africa: | | |
| 79-225 | West African History in Film | 9 |
| 79-226 | African History: Earliest Times to 1780 | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-290 | The Slave Passage: From West Africa to the Americas | 9 |
| Eastern and Southern Asia and the Pacific: | | |
| 79-207 | Asian American History through the Novel | 9 |
| 79-210 | Identity, Ethnicity, and Place in Modern China | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 88-411 | Rise of the Asian Economies | 9 |
| Europe: | | |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-268 | World War I: The Twentieth Century's First Catastrophe | 9 |
| 79-270 | Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present | 9 |
| 79-272 | Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal | 9 |
| 82-320 | Contemporary Society in Germany, Austria and Switzerland | 9 |
| 82-415 | Topics in French and Francophone Studies | 9 |
| 82-441 | Studies in Peninsular Literature and Culture | 9 |
| The Middle East: | | |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| The Americas: | | |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 82-245 | New Directions in Hispanic Studies | 9 |
| 82-343 | Latin America Language and Culture | 9 |
| 82-451 | Studies in Latin American Literature and Culture | 9 |
| 82-455 | Topics in Hispanic Studies | 9 |
| 82-456 | Topics in Hispanic Studies | 9 |

VI. Elective Courses (27 units)

Please schedule an appointment with the academic program manager for guidance in selecting appropriate Thematic and region-based courses that satisfy Global Studies degree requirements.

Students are required to take an additional 27 units of elective courses, selected from one or both of the subcategories below. Any History course (79-xxx) not listed above at the 200 level or higher will count as an elective. In addition, Category IV and V courses listed above that are not used to fulfill those requirements may be counted as electives in addition to the courses listed below.

Students should consult each semester with the Global Studies Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, about new courses approved for the Global Studies major. Students may "double-count" a maximum of four courses for the Global Studies major that are used to fulfill the requirements of other majors and programs. (Note that some of the courses may have prerequisites established by the departments offering them. Students should consult with the academic advisor about how such prerequisites may affect their course of study.)

Please visit the Department of History's Current Courses webpage to see what is available. You can also see a list of electives in the Undergraduate Course Catalog.

Thematic Elective Courses

| | | |
|--------|---|------|
| 57-306 | World Music | 9 |
| 70-365 | International Trade and International Law | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-449 | Race and Media | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 76-468 | Space and Mobilities | 9 |
| 79-101 | Making History: How to Think About the Past (and Present) | 9 |
| 79-204 | American Environmental History | 9 |
| 79-281 | Introduction to Religion | 9 |
| 79-316 | Photography, the First 100 Years, 1839-1939 | 9 |
| 79-324 | #MeToo: Naming and Resisting Gender Violence | 6 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 82-541 | Special Topics in Hispanic Studies | Var. |
| 84-275 | Comparative Politics | 9 |
| 84-310 | International Political Economy | 9 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |

Area-based Elective Courses

| | | |
|--------|---|---|
| 79-216 | Genghis Khan and the Mongol Empire | 3 |
| 79-256 | Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990 | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-269 | Russian History: From Socialism to Capitalism | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| 79-319 | India Through Film | 6 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-322 | Stalin and the Great Terror | 9 |
| 79-326 | Shall We Dance? Culture, Politics, and Movement in the 20th Century | 6 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 82-253 | Korean Culture Through Film | 9 |
| 82-254 | World of Korea, Then and Now | 9 |

| | | |
|--------|---|------|
| 82-273 | Introduction to Japanese Language and Culture | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 82-294 | 19th Century Russian Masterpieces | Var. |
| 82-295 | 20th Century Russian Masterpieces | Var. |
| 82-303 | French & Francophone Cultures | 9 |
| 82-305 | French in its Social Contexts | 9 |
| 82-333 | Chinese Language and Culture | Var. |
| 82-342 | Spain: Language and Culture | 9 |
| 82-344 | U.S. Latinos: Language and Culture | 9 |
| 82-361 | Italian Language and Culture I | 9 |
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-425 | Topics in German Literature and Culture | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-433 | Topics in Contemporary Culture of China | 9 |
| 82-434 | Studies in Chinese Traditions | 9 |
| 82-440 | Studies in Chinese Literature & Culture | 9 |
| 82-473 | Topics in Japanese Studies | 9 |

VII. Senior Capstone Course (12 units)

The research seminar is the capstone course for Global Studies majors and is designed to give students the chance to define and carry out a research project of personal interest. Students are strongly encouraged to incorporate their prior coursework (including foreign language training), study abroad, or internships into their research. Students must earn a final grade of "C" or better for the course to count toward the major.

| | | |
|--------|---------------------------------|----|
| 79-400 | Global Studies Research Seminar | 12 |
|--------|---------------------------------|----|

Global Studies Major — Sample Curriculum

This sample curriculum presents a course of study for completing the requirements for the Global Studies major that includes an optional study abroad semester. Students may declare the Global Studies major and take required courses as early as the second semester of the freshman year and as late as the junior year.

| First-Year | | Second-Year | |
|--|---------------------------------------|---|---|
| Fall | Spring | Fall | Spring |
| 79-201 Introduction to Anthropology or 79-145, Genocide and Weapons of Mass Destruction or 79-189, Democracy and History: Thinking Beyond the Self | 79-275 Introduction to Global Studies | GS Theoretical & Topical Core Course | GS Theoretical & Topical Core Course |
| First-Year Writing Requirement | Language Course or Gen Ed | GS Transnational, Global, Regional Course | GS Transnational, Global, Regional Course |
| Grand Challenge Seminar | 36-200 Reasoning with Data | Language Course or Gen Ed | Language Course or Gen Ed |
| Language Course or Elective | Fourth Course (open) | General Education Course | General Education Course |
| Fifth Course (open) | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |
| 99-101 Computing @ Carnegie Mellon | | | |

| Third-Year | | Fourth-Year | |
|---|---------------------------|--|-----------------------------|
| Fall | Spring | Fall | Spring |
| GS Transnational, Global, Regional Course | STUDY ABROAD* | 79-400 Global Studies Research Seminar | Language Course or Elective |
| GS Elective | GS Elective | Language Course or Elective | Elective** |
| Language Course or Gen Ed | GS Elective | Elective** | Third Course (open) |
| Fourth Course (open) | Language Course or Gen Ed | Fourth Course (open) | Fourth Course (open) |
| Fifth Course (open) | Fourth Course (open) | Fifth Course (open) | Fifth Course (open) |
| | Fifth Course (open) | | |

*Spring semester of the junior year is a popular semester for study abroad. However, Global Studies majors may instead choose to study abroad in spring of sophomore year, or fall of junior year. Students should discuss study abroad and curricular planning with the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240. Study Abroad in a summer program is also an option.

**Many Global Studies majors choose to apply for the senior honors thesis program. The department strongly encourages students to take advantage of this option.

VIII. Additional Major

Global Studies may be elected as a primary or an additional major; the requirements for each are the same. Contact the Academic Program Manager, Dr. Alexandra Garnhart-Bushakra, History Department, Baker Hall 240, to elect the additional major.

The Major in Ethics, History, and Public Policy

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 Location: Baker Hall 236A, 412-268-2880
 sls@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
 Location: Baker Hall 240, 412-268-2880

Patrick Doyle, *Academic Program Manager*, Philosophy Department
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 pdoyle2@andrew.cmu.edu
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The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy 18 units

Choose one of the following two courses:

| | | |
|--------|---|---|
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |

Choose one of the following two courses:

| | | |
|--------|------------------------|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-330 | Ethical Theory | 9 |

II. Ethics and Policy Core 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

| | | |
|--------|--|---|
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-208 | Critical Thinking | 9 |

| | | |
|--------|---|---|
| 80-221 | Philosophy of Social Science | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

III. History and Policy Core 36 units

Choose four of the courses below:

| | | |
|--------|--|---|
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-204 | American Environmental History | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-234 | Technology and Society | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 70-332 | Business, Society and Ethics | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global

justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

| | | |
|--------|--|----|
| 79-449 | EHPP Capstone Course [cross-listed] | 12 |
| 80-449 | EHPP Capstone Course [cross-listed] | 12 |

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

| | | |
|-----------|--|----|
| 21-257 | Models and Methods for Optimization | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 70-208 | Regression Analysis | |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 70-257 | Optimization for Business | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-251 | Empirical Research Methods | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

| Third-Year | | Fourth-Year | |
|----------------------------------|---|--------------------------------|--------------------------------|
| Fall | Spring | Fall | Spring |
| Foundations Course in History | Foundations Course in Law and Social Sciences | EHPP Capstone Course | Ethics and Policy Core Course |
| Foundations Course in Philosophy | Foundations Course in Law and Social Sciences | Ethics and Policy Core Course | History and Policy Core Course |
| Ethics and Policy Core Course | Ethics and Policy Core Course | History and Policy Core Course | Third Course (open) |
| History and Policy Core Course | History and Policy Core Course | Fourth Course (open) | Fourth Course (open) |
| Fifth Course Open | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Minor in Social & Political History (SPH)

Professor Ricky Law, *Director of Undergraduate Studies*, History Department
Location: Baker Hall 238B, 412-268-2880
rlaw@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

www.cmu.edu/dietrich/history/undergraduate/minors/sph.html (<https://www.cmu.edu/dietrich/history/undergraduate/minors/sph.html>)

The minor in Social & Political History involves a minimum of 54 units of History course work.

Curriculum (54 units)

I. Required History Survey Courses (choose two -- 18 units)

Students must complete 18 units (typically 2 courses) from the following list of survey courses:

| | | |
|--------|---|---|
| 79-160 | Introduction to the History of Science | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-204 | American Environmental History | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-206 | Crime and Punishment in Early Modern Europe | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-225 | West African History in Film | 9 |
| 79-226 | African History: Earliest Times to 1780 | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-249 | 20th Century U.S. History | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-260 | Nazi Germany | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-269 | Russian History: From Socialism to Capitalism | 9 |
| 79-272 | Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal | 9 |
| 79-282 | Europe and the World Since 1800 | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-320 | Women, Politics, and Protest | 9 |

II. Elective courses for the Minor in Social & Political History (36 units)

Students must complete 36 elective History units (typically 4 courses). Social & Political History minors have considerable flexibility in choosing their elective courses, but should feel free to consult with the Director of Undergraduate Studies in making their selections.

The Minor in Anthropology

Professor Paul Eiss, *Faculty Advisor*, History Department
Location: Baker Hall 231A, 412-268-6580
pke@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

www.cmu.edu/dietrich/history/undergraduate/minors/anthropology.html
(<https://www.cmu.edu/dietrich/history/undergraduate/minors/anthropology.html>)

The Minor in Anthropology is offered by the Department of History to train students in ethnographic methods and in theoretical understandings of culture. Students examine the evolution, depth, and complexities of ethnography, and explore notions of "culture" in diverse settings, over time and across space. In today's world, students are increasingly aware of the importance of developing a sophisticated approach to culture and its articulation with changes in the domains of the arts, technology, economics, and politics. The Minor in Anthropology, which may be taken alone but especially complements the majors in Global Studies and in Social & Political History, provides students with the tools to link diverse kinds of cultural practices to various aspects of globalization.

The Minor in Anthropology requires that students complete two "Methods" courses (18 units) and four "Anthropological Perspectives" courses (36 units). In addition, 79-201 Introduction to Anthropology is required (9 units), but it may be taken at any time during the student's coursework. Including this course, the Minor in Anthropology totals 63 units.

Curriculum (63 units)

I. General Education Course, Disciplinary Perspectives: Social Sciences (9 units)

This requirement need not be satisfied before beginning the minor.

| | | |
|--------|------------------------------|---|
| 79-201 | Introduction to Anthropology | 9 |
|--------|------------------------------|---|

II. Methods Courses (18 units)

Students must complete 18 units (typically 2 courses) for the Methods Courses, selecting from the list below. (Other courses may fulfill these requirements, with permission of the Faculty Advisor.)

| | | |
|--------|---|---|
| 79-275 | Introduction to Global Studies | 9 |
| 79-317 | Art, Anthropology, and Empire | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

III. Anthropological Perspectives (36 units)

Students must complete 36 units (typically 4 courses) for Anthropological Perspectives Courses, selecting from the list below.

| | | |
|--------|---|---|
| 57-306 | World Music | 9 |
| 79-170 | Introduction to Science, Technology, and Society | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-210 | Identity, Ethnicity, and Place in Modern China | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-219 | Hong Kong, Taiwan and the Idea of "China" | 6 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-224 | Mayan America | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-276 | Beyond the Border | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |
| 79-317 | Art, Anthropology, and Empire | 9 |
| 79-368 | Un-natural Disasters: Societies and Environmental Hazards in Global Perspective | 6 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

Relevant Anthropology courses may be taken at another university (for instance study abroad, or the University of Pittsburgh or other Pittsburgh institutions) with permission of the Anthropology Minor's Faculty Advisor.

Senior Honors

Senior Honors Thesis: Dietrich College

The Dietrich College Honors Program may be undertaken by students completing the major in Social & Political History, the major in Global Studies, or the interdepartmental major in Ethics, History, and Public Policy. An Honors Thesis requires two semesters of work. Eligibility requirements

are set by the College; contact the Associate Dean of Dietrich College for details.

Study Abroad

Study abroad is especially encouraged for all students in the History Department; this experience can help students better understand the relationship between cultural heritage and modern political processes in a host country. To make study abroad successful and determine how specific study abroad programs fit into History Department graduation requirements, History majors should consult with a relevant faculty member and/or with the Academic Advisor.

Faculty

JAY D. ARONSON, Professor of History – Ph.D., University of Minnesota; Carnegie Mellon, 2004–

ALLYSON F. CREASMAN, Associate Professor of History; Associate Head – Ph.D., University of Virginia; Carnegie Mellon, 2005–

PAUL EISSL, Associate Professor of Anthropology and History – Ph.D., University of Michigan; Carnegie Mellon, 2000–

EDDA FIELDS-BLACK, Associate Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 2001–

MICHAL R. FRIEDMAN, Assistant Teaching Professor of History and Jack Buncher Professor of Jewish Studies – Ph.D., Columbia University; Carnegie Mellon, 2012–

WENDY Z. GOLDMAN, Paul Mellon Distinguished Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 1988–

EMANUELA GRAMA, Associate Professor of Anthropology and History; Director of Global Studies – Ph.D., University of Michigan; Carnegie Mellon, 2013–

DONNA HARSCH, Professor of History – Ph.D., Yale University; Carnegie Mellon, 1990–

CARL KUBLER, Assistant Professor of History – Ph.D., University of Chicago; Carnegie Mellon, 2023–

WHITNEY E. LAEMMLI, Assistant Professor of History – Ph.D., University of Pennsylvania; Carnegie Mellon, 2019–

RICKY W. LAW, Associate Professor of History; Director of Undergraduate Studies – Ph.D., University of North Carolina; Carnegie Mellon, 2013–

DEEPA NAIR, Assistant Teaching Professor of History, Carnegie Mellon-Qatar – Ph.D., National University of Singapore; Carnegie Mellon, 2019–

ABIGAIL E. OWEN, Assistant Teaching Professor of History; Director of Education, Steinbrenner Institute for Environmental Education & Research – Ph.D., Columbia University; Carnegie Mellon, 2016–

CHRISTOPHER J. PHILLIPS, Associate Professor of History; Director of Graduate Studies – Ph.D., Harvard University; Carnegie Mellon, 2014–

BENJAMIN REILLY, Teaching Professor of History, Carnegie Mellon-Qatar – Ph.D., University of Pittsburgh; Carnegie Mellon, 2004–

EDMUND RUSSELL, David M. Roderick Professor of Technology and Social Change and Professor of History – Ph.D., University of Michigan; Carnegie Mellon, 2019–

SCOTT A. SANDAGE, Associate Professor of History – Ph.D., Rutgers University; Carnegie Mellon, 1995–

EZELLE SANFORD III, Assistant Professor of History – Ph.D., Princeton University; Carnegie Mellon, 2021–

STEVEN SCHLOSSMAN, Professor of History; Director of Ethics, History, and Public Policy – Ph.D., Columbia University; Carnegie Mellon, 1988–

NICO SLATE, Professor of History; Department Head – Ph.D., Harvard University; Carnegie Mellon, 2009–

JOHN SOLURI, Associate Professor of History – Ph.D., University of Michigan; Carnegie Mellon, 1999–

LISA M. TETRAULT, Associate Professor of History – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2005–

NOAH THERIAULT, Assistant Professor of Anthropology and History – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2017–

JOE WILLIAM TROTTER JR., Giant Eagle University Professor of History and Social Justice – Ph.D., University of Minnesota; Carnegie Mellon, 1985–

BENNO R. WEINER, Associate Professor of History – Ph.D., Columbia University; Carnegie Mellon, 2015–

Affiliated Faculty

STEPHEN BROCKMANN, Professor of German with Courtesy Appointments in English and History – Ph.D., University of Wisconsin Madison; Carnegie Mellon, 1993–

JOSEPH E. DEVINE, Associate Dean for Undergraduate Studies, Dietrich College of Humanities and Social Sciences – D.A., Carnegie Mellon University; Carnegie Mellon, 1979–

TIMOTHY HAGGERTY, Principal Lecturer – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–

JEFFREY HINKELMAN, Senior Lecturer and Director of the Film & Visual Media Program, English Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

ANDREW S. RAMEY, Director of Advising, Dietrich College of Humanities and Social Sciences – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

CHRISTOPHER WARREN, Professor of English and Associate Department Head with a Courtesy Appointment in History – D. Phil., University of Oxford;

Emeriti

CAROLINE JEAN ACKER, Associate Professor Emeritus of History – Ph.D., University of California, San Francisco; Carnegie Mellon, 1993–

LAURIE Z. EISENBERG, Teaching Professor Emeritus of History – Ph.D., University of Michigan; Carnegie Mellon, 1992–

KATHERINE A. LYNCH, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1980–

RICHARD MADDOX, Professor Emeritus of Anthropology and History – Ph.D., Stanford University; Carnegie Mellon, 1993–

JOHN MODELL, Professor Emeritus of History – Ph.D., Columbia University; Carnegie Mellon, 1982–

DANIEL P. RESNICK, Professor Emeritus of History – Ph.D., Harvard University; Carnegie Mellon, 1966–

JUDITH SCHACHTER, Professor Emeritus of Anthropology and History – Ph.D., University of Minnesota; Carnegie Mellon, 1984–

DONALD S. SUTTON, Professor Emeritus of History and Anthropology – Ph.D., Cambridge University, England; Carnegie Mellon, 1969–

JOEL A. TARR, Richard S. Caliguiri University Professor of History and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1967–

Department of History Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

79-101 Making History: How to Think About the Past (and Present)

Intermittent: 9 units

Who makes history? This apparently straightforward question is at the heart of studying the past, but it is also an important question to answer if we are to understand the world around us. Being able to answer the question "Who and what caused changes to political, cultural, economic, and environmental systems?" is fundamental to thinking about the past, but it is also essential to analyzing current issues as widespread and yet connected as economic inequality, social justice, and climate change. "Making History" is an introductory course ideal for students who are curious about the past and want to learn how to become better critical thinkers by applying its lessons to the present. The course explores how history is made on two levels: both the historical events themselves and how those events are documented, interpreted, and remembered. In other words, making history is not just about understanding what happened, but what it meant to different groups of people then and what it means to different groups of people now. We'll visit some famous (and not-so-famous) historical events and actors to learn about how individual choices combine with deeper structural factors, like gender, race, environment, and class to "make history." Along the way, we'll also encounter different ways to interpret the past, drawing upon the latest scholarship to understand how historians think about the past and #8212; and present. Students will be encouraged to synthesize what they learn in class to develop their own critical perspectives on their lives and the world around them.

79-104 Global Histories

Fall and Spring: 9 units

Human activity transcends political, geographical, and cultural boundaries. From wars to social movements, technological innovations to environmental changes, our world has long been an interconnected one. Acquiring the ability to understand such transnational and even worldwide processes is an indispensable part of any college education. This course provides students with an opportunity to develop the skills and perspectives needed to understand the contemporary world through investigating its global history. All sections are comparable in their composition of lectures and recitations, required amounts of reading, and emphasis on written assignments as the central medium of assessment. The sections all aim to help students: (1) master knowledge through interaction with the instructors, reading material, and other students, (2) think critically about the context and purpose of any given information, (3) craft effective verbal and written arguments by combining evidence, logic, and creativity, and (4) appreciate the relevance of the past in the present and future.

79-120 Introduction to African American History: Black Americans and the World

All Semesters: 9 units

Exploring the history of Black Americans requires a global perspective. Beginning with early modern African civilizations, the transatlantic slave trade, the global age of revolutions, the implementation of transnational regimes of racial segregation, to the growth of transnational movements for civil and human rights, this course surveys the history of Black Americans from a global perspective. It analyzes how Black Americans conceived of their social position in relation to others in the world. It also explores how perspectives from across the world made sense of Black Americans. This course will follow African-descended people as they theorized, moved, migrated, and traveled throughout the world. From this perspective, students will learn about the diasporic dimensions of Black American identity. Students will also trace the historical circulation of African-descended people, knowledge, culture, and technologies. Students will analyze the important themes of freedom, movement, and migration from a global perspective. Through this course, students will learn that Black American historical actors have and continue to understand their position not only within the domestic social and political spheres of the United States but also in the global order of states and societies. From their marginalized social position, Black Americans, therefore, have articulated alternative frameworks for understanding the United States, the West, and the world. This is an introductory survey course.

79-145 Genocide and Weapons of Mass Destruction

Fall and Spring: 9 units

[Note: Students who have passed 79-104, Global Histories: Genocide and Weapons of Mass Destruction, may not enroll.] Can you imagine being responsible for the deaths of hundreds, thousands, or even millions of people? No? Almost everyone who ended up committing unspeakable atrocities had not been able to either. In fact, many of them still would not face their responsibility even after their complicity was proven beyond doubt. Some convinced themselves, often sincerely, that there was no choice or that someone else was actually responsible. Others found reasons that justified, in their minds at least, taking many lives. Still others managed to forget that they had blood on their hands. How could anyone do such terrible things? And more important, can you be sure that you would not act like them under the right circumstances? Through the history of genocide and weapons of mass destruction, this course will teach you to look out for factors that turn ordinary people into mass killers. You will explore why conflicts break out and potential solutions. You will also learn to see from multiple perspectives and to be humble before history. We focus on genocide and weapons of mass destruction because stopping them is a top priority in global affairs today. Our exploration will begin with the European encounter with the Western Hemisphere and continue to 19th-century imperialism, the Holocaust, the atomic bombings of Japan, the Cold War, and decolonization and independence. At the end of our journey, you will have grasped the concepts and historical facts of genocide and weapons of mass destruction. You will also come to appreciate the significance of unintended consequences and the ambiguity of human progress, a realization that will guide you in life.

79-149 Ancient Rome: What Have the Romans Ever Done for Us?

Intermittent: 9 units

The Romans are nowhere and everywhere in our world. Hundreds of years after anyone could plausibly claim to be Roman, the influence of ancient Rome is still palpable in our political institutions, religions, languages, geography, art, law, architecture, technology, and so much more. And not just in Europe. The legacy of ancient Rome can be felt in the Americas and elsewhere in the world. It affects how we think about the tension between West and East, the definitions of civilization and barbarism, and citizenship and belongingness in a multiethnic society. How did ancient Rome rise and how did it fall? Did it fall at all? How can a people who flourished about two thousand years ago still play a role now? If ancient Rome's impact is still so broad and deep, what lessons can or should we draw from the Romans? This course will explore these questions by tracing the history of Rome from its mythical and actual foundations to its expansion, gradual decline, and repeated renewals. At the end of the course, students will be able to answer that memorable question in Monty Python's *Life of Brian*: What have the Romans ever done for us?

79-160 Introduction to the History of Science

All Semesters: 9 units

This course provides an introduction to the history of modern science in Europe and North America, from the Enlightenment to the mid-twentieth century. Our goal is to understand scientific theories and practices on their own terms and as products of their own contexts, rather than as a progression of developments moving inevitably toward the present. The course seeks to explore both how and why science has become the dominant way of knowing about the natural world, as well as how scientific activity intersects with the history of religion, war, commerce, and the state. The course also introduces students to the history of science as a standalone discipline, and in particular to the similarities and differences with other objects of historical inquiry (art, politics, etc.).

79-170 Introduction to Science, Technology, and Society

Intermittent: 9 units

Science and technology are among the most powerful transformative forces in today's global society. They shape the way we think about ourselves, the world around us, and even what is possible in the future. This course provides an introduction to Science and Technology Studies, a vibrant interdisciplinary field that examines the ways that science and technology interact with contemporary politics, culture, and society. Using theories and methods from history, philosophy, anthropology, sociology, and public policy, we will examine: the nature of scientific and technical knowledge; how facts are produced both inside and outside the laboratory; how politics and societal values impact scientific inquiry and the development of new technologies; whether objectivity is possible; what expertise is and the role that experts play in the world today; how our understanding of science and technology has been enhanced by focusing on issues of race, sex, gender, sexuality, and class; as well as the imperative to make science and technology more equitable and just than they have been in the past. Specific topics covered will include the development of military technologies like radar and the atomic bomb, genetic engineering and cloning, artificial intelligence, social media, transportation infrastructure, racial classification, gender identity, and the Covid-19 pandemic, among others. This course is meant to serve as a foundation for the new Science, Technology, and Society major, but it is open to anyone concerned with the social and political dimensions of science and technology.

79-175 Moneyball Nation: Data in American Life

Intermittent: 9 units

From conducting clinical trials and evaluating prisoners' parole cases to drafting professional ballplayers, we increasingly make decisions using mathematical concepts and models. This course surveys the development of and #8212;and resistance to and #8212;such tools by grounding them in the recent cultural history of the United States. Focusing on baseball, medicine, and the law, we'll explore how and why Americans have come to believe mathematical and computational methods can solve complicated problems, even in seemingly unrelated moral, political, and social domains. The course encourages students to think critically about the wider implications of these transformations by situating their development historically.

79-189 Democracy and History: Thinking Beyond the Self

Fall and Spring: 9 units

[Note: Students who have passed 79-104, Global Histories: History of Democracy, may not enroll.] What is the best way to run a country? What is the worst? Democracy has been called both the best and worst form of government. Either way, as almost all countries in the world claim to be a democracy, chances are you come from one of them. What does it mean to live in a democracy? In essence, it means thinking beyond the self and from the perspectives of other people. It means looking for facts but being open to different interpretations. And it means taking responsibility to think critically and independently. These traits are also necessary for understanding history. This course will train you in the skillset and mindset of a historian so you can act democratically. You will learn to tell historical facts from opinions and to see from various angles. The course will also push you to think for yourself, and to argue persuasively for your own position. These skills of thinking historically are useful not just for school or work, but they are also indispensable to a democratic society. Democracy is chosen as the course theme because it is a feature that sets humans apart from other organisms. Knowing the history of democracy is thus knowing what it means to be human, which is the essence of the humanities. Our investigation will begin with ancient Rome and continue to revolutionary France, Weimar Germany, modern Japan, the Chinese nation, and the Iranian nation. At the end of our journey, you will have gained a basic appreciation of the philosophical appeal and practical challenges of democracy, so that you will be able to decide for yourself what role democracy should play in your life and vice versa.

79-198 Research Training: History

Fall and Spring: 9 units

This course is part of a set of 100-level courses offered by Dietrich College departments as independent studies for second-semester freshmen and first- or second-semester sophomores in the College. In general, these courses are designed to give students some real research experience through work on a faculty project in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regularized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. Prerequisites/restrictions: For Dietrich College students only; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question. By permission of the relevant professor and the Director of Undergraduate Studies. Students sign up for these courses through both the History Department and the Dean's Office. Section A: The Right to Vote: An Unexpected History, L. Tetrault Section B: The History of Biostatistics, C. Phillips Section C: From "Banana Republic" to "Cup of Excellence," Explaining the rise of Honduras in the Global Coffee Business, J. Soluri Section D: Mapping Segregated Medicine, E. Sanford

Course Website: <https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html>

79-200 Introduction to Historical Research & Writing

Fall and Spring: 9 units

Introduction to Historical Research acquaints students with how historians practice their craft in interpreting events from the past. As a class, we will work together through a variety of tools in the historian's toolbox, using episodes from American history as case studies. By the second half of the semester, students will have identified their own topics, in any time period or field of history, and will write research papers incorporating the analytical techniques covered earlier. The goal is for students to learn the skills required to identify a research topic, find and work with many kinds of sources, create a strong thesis statement, design a persuasive paper, and produce a properly formatted and well written research paper.

79-201 Introduction to Anthropology

Intermittent: 9 units

Anthropologist Ruth Benedict claimed that anthropology's mission is truly to "make the world safe for human difference." Cultural anthropologists "make the strange familiar and the familiar strange," attempting to understand the internal logic of cultures which might, at first glance, seem bizarre to us. At the same time, anthropologists probe those aspects of our own society which might appear equally bizarre to outsiders. The goal of this course is to raise questions basic to the study of culture and social relationships in a multitude of contexts. We will also discuss the particular research methods informing anthropology, as well as anthropologists' relationship to the people they study, and the responsibilities informing those relationships. The readings focus on topics that have long captured anthropologists' attention and that continue to be intensely debated: social inequality, race, colonialism, body, kinship, religion, gender, social lives of things, globalization and migration. Through written work, including ethnographic readings and a novel, films, and in-class discussions, we will examine how anthropology makes us more aware of our own culturally ingrained assumptions, while broadening our understanding of human experiences. This course is structured as a combination of lectures and seminar discussions. In the first part of the course, I will give a lecture every week, followed by a class session that will focus solely on discussing the readings and key concepts. In the second part of the course, I will introduce the readings by placing them within larger debates, but the course will become more discussion oriented.

79-202 Flesh and Spirit: Early Modern Europe, 1400-1750

Intermittent: 9 units

This course examines European history from the Black Death to the French Revolution, a period known to history as the "early modern" period. That is, it marks a period in European history that was not quite medieval, and yet not quite modern. Many features of modern society, such as the nation-state, free-trade economies, religious pluralism, scientific rationalism, and secular culture trace their origins to the early modern era, yet the period was also marked by important continuities with the Middle Ages. During this course, we will explore how Europeans re-imagined their world in its transition from the medieval to the modern. Topics to be considered will include the "renaissance" of the arts, the problems of religious reform, exploration and colonialism, the rise of science, and the expansion of the state. Through these developments, we will focus on Europeans' changing notions of the human body, the body politic, and the natural world, as well as their re-interpretations of the proper relation between the human and the divine, the individual and the community, and the present and the past.

79-203 The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990

Intermittent: 9 units

During the last two centuries, Central and Eastern Europe has been a political laboratory and #8212;a region in which various political actors had attempted to launch and develop radical political and social experiments, from imperial reforms meant to strengthen and modernize the Habsburg empire, to the ethnic cleansing promoted by Nazi Germany and their acolytes in the region, to the attempts at establishing of a new social order under the post-WWII communist regimes. An understanding of the profound and rapid political and social changes that have occurred in this region will enable you to see global politics in a new light, and better understand the modern era. This course is a survey of the history of modern Central and Eastern Europe, from late 18th to late 20th century. It begins with a focus on modern Habsburg empire, the rise of nationalism in mid 19th century, and the demise of the Austro-Hungarian empire following the First World War. It continues with an examination of the rise of illiberal politics during the interwar era, the Second World War, and the establishment of the communist regimes and the Soviet sphere of influence during the Cold War. Course materials include secondary historical analyses, primary sources, memoirs, and documentaries. The course will rely heavily on the format of interactive lectures a combination of lecture and discussion, which will productively challenge the students to engage with the material in a critical manner, and will help them contextualize and enrich the knowledge they gain from the course readings.

79-204 American Environmental History

Intermittent: 9 units

This course examines how people in North America have interacted with their surroundings from the end of the last ice age to the present.

79-205 20th Century Europe

Intermittent: 9 units

This course surveys the history of Europe from 1900 through the present. We shall examine some of the major political trends and social/economic changes of the last century, including: the collapse of Europe's multiethnic empires and the rise of the modern nation-state; the extraordinary violence and impact of WWI and the rise of ethno-nationalism and fascism during the inter-war period; The Spanish Civil War, WWII and the War in the Balkans in the 1990s. We will also examine Communism and its collapse; colonial resistance and the process of decolonization; and the creation of the European Union. In addressing contemporary Europe, we shall discuss: the re-emergence of ethno-nationalism and rising anti-immigrant sentiment and antisemitism over the last decades; cultural and political debates surrounding Islam and Muslims; contemporary debates over the memory of the Holocaust, and Russia's brutal war against Ukraine. Primary sources, academic articles, memoir and film will be used in the classroom to explore these topics. Classes will combine lecture, discussion and group work.

79-206 Crime and Punishment in Early Modern Europe

Intermittent: 9 units

This course will examine European legal and social institutions and their role in defining and punishing crime in the early modern era (c. 1400-1800). European society was fundamentally transformed in this period of transition between the medieval and the modern eras, and the laws and legal systems that exist in the Western world today reflect those influences at the deepest levels. This course will focus on how shifting definitions of "crime" and "punishment" reflected prevailing societal attitudes and anxieties toward perceived acts of deviance and persons on the margins of society. Assigned readings will examine the evolution of early modern European criminal court systems and the investigation and punishment of crime, focusing in particular on the historical debates concerning the use of torture and capital punishment and the evolution of modern policing and prisons. It will also address the criminalization of social deviance (witches, religious minorities, and other outcasts) and the legal enforcement of sexual norms and gender roles. The course concludes with an examination of current debates concerning criminal justice reform, policing, torture, and criminal punishment.

79-207 Asian American History through the Novel

Intermittent: 9 units

This course examines the interwoven histories of migration, language, and identity formation and re-formation in Asian American experience. How have migrant and diasporic identities been represented in fictional (or quasi-fictional) terms? How have factors such as race, religion, class, gender, and sexuality shaped everyday Asian American life? And how can literary sources enrich our understanding of such historical experiences? Course readings consist primarily of novels, representing a variety of Asian ethnicities and experiences, by authors including Gaiutra Bahadur, Carlos Bulosan, Maxine Hong Kingston, Joy Kogawa, Chang-Rae Lee, and John Okada. These works are supplemented by selected historical documents and short lectures to shed additional light onto the sociohistorical contexts and issues under study.

79-208 Witchcraft and Witch-Hunting

Intermittent: 9 units

Between the late 15th and the early 18th centuries, many Europeans became convinced that their society was threatened by a conspiracy of diabolic witches. Although Western beliefs in witchcraft and "devil worship" dated back to antiquity, the 16th and 17th centuries witnessed the most intense campaign of witch-hunting in all of Europe's history. Before it was over, the "Great European Witch-Hunt" of the early modern era cost the lives of thousands across Europe and in its colonies. And although the witch-hunts in early modern Europe and its colonies gradually came to an end, beliefs in witchcraft persist into the modern era and, in many parts of the world today, continue to generate campaigns of popular violence against alleged perpetrators. This course examines witchcraft beliefs and witch-hunting in historical perspective in both their European and colonial contexts. In addition to the early modern witch-hunts, it will address modern witchcraft beliefs and consider witch-hunting as a global problem today. It will focus on the origin and rationale of witch beliefs, the factors driving the timing and intensity of witch-hunts, and the patterns of accusations. Throughout, we will examine the many historical and regional variations in witch beliefs and prosecutions and explore how they reflect major social and cultural issues such as the relationship between "popular" and "elite" culture; religious change; state formation; gender and patriarchy; and the rationalization of law, medicine, and science. This course satisfies one of the elective requirements for the Religious Studies minor.

79-210 Identity, Ethnicity, and Place in Modern China

Intermittent: 9 units

Within popular imagination, China is often considered to be the world's oldest nation. As a result, concepts such as "China" and "Chinese" have become so embedded in our consciousness that we often fail to consider how, like all identities, ideas of Chinese-ness have been constructed hand-in-hand with the invention of the modern Chinese nation-state. This course examines nation-making in China from the outside in. We privilege avenues of inquiry that challenge state-sponsored narratives, complicate the hegemonic notion of "Han" as a majority identity, and consider ways in which processes of state consolidation and majoritization have subjected various ethnic, subethnic, diasporic, linguistic, gender, and religious communities to discrimination, marginalization, exclusion, and in some cases state and majoritarian violence. Rather than uncritically accepting the notion that China is a uniquely "historical nation," we instead consider the possibility that the Chinese state and nation are products of the same transglobal currents such as imperialism, settler colonialism, assimilation, minoritization, and exclusion that has made our modern world. Whenever possible, we employ historical texts, short stories, novels, memoirs, and film produced by members of disadvantaged, marginalized, and/or targeted communities in order to demonstrate how and why historical experiences and memories for example among "ethnic minorities" differ from the Han majority and from state orthodoxy, and why these differing perspectives matter.

79-211 Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange

Intermittent: 9 units

When you hear the term "Southeast Asia," what comes to mind? The US War in Vietnam? The ruins of the Angkor civilization? Rich culinary traditions? Or perhaps your own heritage? However you imagine it, Southeast Asia is an incredibly diverse and dynamic region that has long been integral to world affairs and whose importance continues to grow. This course offers a wide-ranging survey of Southeast Asia's peoples, their histories, and some of the issues they face today. Together we will explore the region as a "global crossroads," where the world's religions, economies, cultures, and politics come together in generative, sometimes traumatic, and often surprising ways.

79-212 Jim Crow America

Intermittent: 9 units

Michelle Alexander's *The New Jim Crow* (The New Press 2010) has drawn attention to the ways that American institutions and social systems continue to produce racial inequalities. The recent failure of federal voting rights bills in the United States Congress and the proliferation of state-led efforts to constrain voting rights have led activists to claim "Jim Crow 2.0." Using these present-day assessments as a point of departure, this course introduces students to the Jim Crow period of American history spanning the late nineteenth century to the mid-twentieth century. From the 1890s to the 1950s, Black freedoms were limited by the policies and practices of racial segregation in the Jim Crow system of American apartheid. This course critically examines Black life in Jim Crow America, from the halls of federal power, to the every-day practices of racial subjugation and resistance. It examines cross-cutting themes: how racial segregation structured the legal, social, economic, and political sectors of American life; the role of national, state, and local policy mandating racial segregation; African American modes of resistance; vigilante and state racial violence. This course will also endeavor to make connections between the consequences of anti-Black racism and the social life of other American minoritized populations. Throughout the course, as an exercise in historical interpretation and periodization, students will consider the question: Is this current moment "Jim Crow 2.0.?"

79-215 Environmental Justice from Conservation to Climate Change

Intermittent: 9 units

What is environmental justice? Who are environmental justice activists, what do they believe, and how do they act? This course will explore these questions by reading, discussing, and comparing the biographies of famous activists (e.g. Rachel Carson, Chico Mendes, Ken Saro-Wiwa, Wen Bo, Berta C and #225;ceres, and Greta Thunberg) and not-so-famous, "everyday" people in order to understand how and why they have struggled against disproportionate exposure to pollution, government or corporate usurpation of life sustaining resources, or the loss of a home due to climate change. Course readings and discussions will use historical examples to understand connections between "social" problems such as racism and "environmental" problems such as climate change. We will evaluate how social identities, political ideologies, and ecological contexts have influenced the ideas and actions of environmental justice activists. Class discussions, short, written responses to readings, and a final project will encourage students to engage in critical analysis of environmental justice and self-reflect on their individual and collective responsibilities.

79-216 Genghis Khan and the Mongol Empire

Intermittent: 3 units

This course examines the rise, rule, and impact of the Mongol Empire on global history. In the 13th century, Eurasia was shaken by a force contemporary chroniclers likened to an apocalypse. Within a few decades, horsemen under the command of Chinggis (Genghis) Khan swept out of the northeastern steppe to establish the largest land empire the world would ever know. Few events in world history have inspired such fear and awe. However, the Mongol period also ushered in the so-called pax Mongolica, the first period of sustained contact and exchange across Eurasia as people, technologies, arts, biodiversity, and ideas spread throughout the Mongol domains and beyond. Questions to be examined include: Who was Genghis Khan and how did he lead a little known nomadic people to conquer much of the known world? What cultural and technological innovations aided the Mongols rise and conquest? How did Genghis's successors rule their vast, diverse domains? What role did religion play in Mongol Eurasia? Why did a unified Mongol empire fall apart in such a relatively short period of time? And how did the Mongols and their empire help shape the world we live in today?

79-218 Tiananmen Square and Popular Protest in Modern China

Intermittent: 6 units

On June 4, 1989, the world watched as tanks rolled into Beijing's Tiananmen Square ending what had been six weeks of student-led protest calling for reform of the Chinese Communist Party and its policies. This was not the first time students had gathered at Tiananmen to demand political change. Exactly seventy earlier, student-led protests launched the May 4th Movement, a social and intellectual revolution that fundamentally changed China and helped birth both the Nationalist Party of Chiang Kaishek and Communist Party of Mao Zedong. This class examines the causes and consequences of popular protest in modern China. While the focus is on the protests of 1919 and 1989, we will also look at other popular protests, including the Cultural Revolution (1966-1969), Democracy Wall Movement (1979), post-Tiananmen protests among workers, farmers, and ethnic minorities (especially Tibetans and Uyghurs), and the current protests in Hong Kong.

79-219 Hong Kong, Taiwan and the Idea of "China"

Intermittent: 6 units

Starting with the core question, "What is China?", this mini-course explores the recent histories of Hong Kong and Taiwan to investigate questions of identity, nationalism, ethnicity, exceptionalism, colonialism, and historical memory in "Greater China." While both Hong Kong and Taiwan are generally considered to be "Chinese," neither ever has been fully included in the modern Chinese nation-state. The agreement that transferred Hong Kong from British rule to PRC control in 1997 enshrined the idea of "One Country, Two Systems," a guarantee that Hong Kong's political, legal, and economic systems would not be altered for fifty years. One Country, Two Systems has also been offered as a blueprint for "reunifying" Taiwan with Mainland China. However, in recent years publics in both Hong Kong and Taiwan not only increasingly resist political reunification with the PRC, but more and more identify themselves as citizens of either Hong Kong or Taiwan rather than members of a singular Chinese nation. This has led to mass protests in Hong Kong and calls for true independence in Taiwan. Other topics that may be discussed include subethnic identity and ethnic minorities in modern China and the Chinese diaspora.

79-220 Screening Mexico: Mexican Cinema, 1898 to Present

Intermittent: 6 units

This mini-course is a survey of Mexican cinema from its origins in silent film to the present. Some areas of focus will include documentary footage and films of the Mexican Revolution (1910-1920), films of the Mexican "Golden Age" (1930-1960), and "New Mexican Cinema" from the 1990s forward. We will explore cinema as a window on Mexico's changing social, cultural and political dynamics, and as a way to probe such topics as: changing conceptions of Mexican identity; political critique and revolutionary movements; and urbanization, migration and the "drug war" in contemporary Mexico.

79-222 China and the Second World War

Intermittent: 6 units

This course is an introduction to China's experiences during the Second World War. Although China's involvement in the war is often considered to be of secondary importance, it was in China that the war began (1937) and China was occupied longer than any other allied country. Throughout, sustained Chinese resistance ensured that 1.5 million Japanese troops could not be transferred to other war theaters. However, it came at great cost. Only the Soviet Union suffered more casualties during World War II, perhaps as many as 20 million lives lost. In this class we explore the roots of the Second World War in both China and Japan, trace the political and military history of the war, contemplate the terrible levels of violence that were inflicted upon the Chinese population, including violence committed by Chinese forces, seek to understand the social impact of the war, and think about the consequences of the war for China and the world, including the rise of Mao Zedong's Chinese Communist Party. We also explore the manner in which the war is commemorated in China and Japan and the role communal memory plays in galvanizing nationalism among both the Chinese and Japanese publics.

79-223 Mexico: From the Aztec Empire to the Drug War

Intermittent: 9 units

This course provides a survey of Mexican history and culture over a variety of periods, from the rise of the Aztec empire, to Spanish conquest and colonization, to national independence, to the Mexican Revolution and contemporary Mexico. A wide range of topics will be addressed, such as: race, ethnicity, and indigenity; state formation and politics; national identity and the politics of memory; the border, migration, and the deportation regime; and the drug war. Students will discuss historical and anthropological scholarship on Mexico, but will also consider cultural documents of various kinds, like Mexican music, art, cinema and food. This course is interdisciplinary, bringing together the perspectives of both history and anthropology. A majority of readings for the course are primary documents-historical, but also cultural texts-and hence a good amount of time is spent considering issues around primary source interpretation in historical and cultural terms. This course stresses the importance of taking account of difference (social, cultural, historical) as we consider large questions about history, politics, and in some cases, policy.

79-224 Mayan America

Intermittent: 9 units

This course will explore the history and culture of the Maya from before the European conquest of the Americas to the present. After a survey of ancient Mayan society and of the European conquest of Mexico and Central America, we will consider the experience of the indigenous Maya under Spanish colonial rule and under the rule of Latin American nation-states in the nineteenth and twentieth centuries. Finally, we will cover the recent history of political conflict and military repression in Guatemala, the Zapatista uprising in southern Mexico, and increasing Mayan migration to the United States. Drawing upon the varied perspectives of archaeology, cultural anthropology, and social history, this course will explore several recurrent themes in Mayan America, such as: conquest, adaptation and resistance; indigenous political and communal organization; popular religion, prophecy and apocalypse; Mayan cultural and ethnic identity; "tradition" and "modernity"; state violence and human rights; and indigenous political and cultural mobilization at the local, national, and transnational levels.

79-225 West African History in Film

Intermittent: 9 units

West Africa is a vibrant, diverse, and rich region, which has had the largest influence demographically, culturally, socially, and linguistically on the Americas. This course will examine West Africa's history from the pre-colonial to the independence period. It will cover such topics as states vs. stateless societies, urbanization, trans-Saharan trade, Islamization, European interaction, the trans-Atlantic slave trade, colonialism, cash crops, missionaries, nationalism, and independence. Students will understand how this dynamic region changed over time as a result of internal factors, such as state formation, as well as external factors, interaction with Muslim and European traders. Students will also be exposed to the variety of sources used by historians to reconstruct West Africa's rich history. The course will use historical films by some of West Africa's most famous filmmakers, such as Ousman Sembene, to illustrate the diversity of the region and its historical change over time. Course includes two class meetings and mandatory film screenings on Wednesdays from 6:40-9:30pm.

79-226 African History: Earliest Times to 1780

Intermittent: 9 units

A beginning point for this course will be the question: how do historians reconstruct history when few written sources are available? Breaking disciplinary boundaries, the course will draw on linguistics, "climateology," archaeology, and anthropology to reconstruct dynamic social, cultural, political, and economic processes in Africa before the arrival of Europeans and before the availability of written source materials. When written sources are available, the course will interrogate them to illuminate the changes that occurred in African societies during the early period of contact with Europeans. Lastly, by focusing on long-term processes, such as economic specialization, urbanization, and Islamization, the course will begin to put the slave trade in an African-centered perspective.

79-227 Modern Africa: The Slave Trade to the End of Apartheid

Intermittent: 9 units

The course is designed to give students an understanding and appreciation of African history and culture from the "inside out." Though it deals with the period of European expansion in Africa, it is centered on African language/ethnic groups, villages, and individuals as historical actors who daily make collective and personal decisions to pass down, innovate, and borrow practices, technology, spiritual systems, etc. in the face of social, political, and economic realities. The course is also designed to get students thinking critically about how historians select and interpret sources to construct and reconstruct history at these different levels.

79-229 The Origins of the Palestinian-Israeli Conflict, 1880-1948

Intermittent: 9 units

This course considers the historical origins of the contemporary Arab-Israeli conflict, beginning with the decline of the Ottoman Empire and the rise of Arab nationalism and Zionism in the late 19th century and emphasizing the period of the British Mandate over Palestine (1920-1948). Students will move beyond textbooks to explore primary source documents, maps, photographs, biographies and historical testimony. For five weeks in the middle of the semester, students will immerse themselves in an extended role-playing exercise, "The Struggle for Palestine, 1936," an elaborate simulation game linked to Barnard College's "Reacting to the Past" program. Students portraying British examiners, specific Arab and Zionist characters and journalists will recreate the activities of the 1936 Royal Commission that came to Palestine to investigate the causes of an Arab rebellion and Arab-Jewish strife. This historical reenactment experience constitutes an exciting pedagogical opportunity for delving deeper into the topic material than regular coursework allows. All the role-playing will take place during regular class time, but students should be aware that they will need to devote outside time for preparation and research. Outstanding attendance is also a requirement. Regular classroom activity resumes at the end of the five weeks. The goal of the course is for students to develop a nuanced understanding of the varying goals and priorities of all the actors in Mandate Palestine. Running throughout the course is the question, was peace ever possible?

79-230 The Arab-Israeli Conflict and Peace Process since 1948

Intermittent: 9 units

The course begins in 1948 with the establishment of the State of Israel, the Palestinian dispersal and the first of many Arab-Israeli wars, and continues up to the present. The examination of the many facets of the Arab-Israeli and Palestinian-Israeli conflicts is accompanied by attention to primary source documents and to the search for peace and its frustration. By semester's end, students should be able to stand in the shoes of all relevant actors and understand each one's perspective, regardless of their own sympathies. Of particular interest is the question, why have efforts to resolve the conflict so often failed? What modifications to past approaches might prove successful? The professor does not aim for students to arrive at any particular position, but rather that students should understand the historical forces at work and that their individual opinions should be knowledgeable, not identical. The course culminates in an intensive week-long role-playing game in which we will conduct simulated Arab-Israeli negotiations. The simulation game experience is an exciting pedagogical experiment and an opportunity for delving deeper into the topic material than regular coursework allows.

79-232 Arabian Peninsula Environmental History

Intermittent: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. This course will look at the history of the Arabian Peninsula from a fresh perspective, examining human/environmental interactions over a long stretch of time. In contrast to the way that Arabian history is typically taught in academia, this course will take the pre-Islamic period of Arabian history (al-jahiliyya) as seriously as the post-Islamic period, and will focus on continuities between the two periods as much as discontinuities. What is more, while conventional histories of the Arabian Peninsula focus on political and religious affairs, this course will try to understand Arabian history on a deeper level by focusing on the lifeways of the Arabian people, including pastoralism, oasis "bustan garden" agriculture, fishing and pearling, and shifting patterns of long-distance trade. What is more this course will draw heavily from material from other disciplines, especially medical sciences, to better understand patterns of change over time. Finally, this course will examine to what degree these older patterns of human/landscape interactions are still valid for the Arabian Peninsula today, which has undergone a transformation almost unparalleled in world history due to the discovery natural gas and oil.

79-234 Technology and Society

Intermittent: 9 units

How has technology shaped human society? And how have human beings shaped technology in return? This course investigates these questions across history—from stone tools, agriculture, and ancient cities to windmills, cathedrals, and the printing press; from railroads, electricity, and airplanes to atom bombs, the internet, and the dishwasher. In analyzing these tools, we will explore the dynamic relationships between technological systems and the social, political, religious, artistic, and economic worlds in which they emerged. We will also pay particular attention to technology's effects, asking both who benefited from and who was harmed by technological change. By the end of the course, students will be able to reflect critically on how humanity chooses which technologies to exploit and how human societies have been transformed by these choices.

79-237 Comparative Slavery

Intermittent: 9 units

This course will examine the pervasive, world-spanning institution of human slavery. Although the time frame this course deals with is broad - from the rise of complex societies in the ancient world to slavery-like labor systems in the modern era - this class will focus more thoroughly on a few case studies, especially slavery in the Middle East and sub-Saharan Africa, the US, and the Caribbean. These disparate examples will be related to a number of core themes, including race, class, family, gender, religion, national identity and underdevelopment.

79-238 Modern African American Film: History and Resistance

Intermittent: 6 units

This course explores the historical and contemporary impact of resistance on and in African American film during the twentieth and twenty-first centuries. We will consider how filmmakers use narrative and aesthetics to represent, address, and combat anti-blackness, attend to filmmaking itself as a potential act of resistance, and cultivate our own "oppositional gazes" as spectators and critics. The five films we will watch are: · Within Our Gates (dir. Oscar Micheaux, 1920) · Do the Right Thing (dir. Spike Lee, 1989) · Daughters of the Dust (dir. Julie Dash, 1993) · The Watermelon Woman (dir. Cheryl Dunye, 1996) · Moonlight (dir. Barry Jenkins, 2016) Access to the films and any supplemental readings will be provided; unless otherwise stated on the syllabus, students will be expected to carefully study this material prior to each class. Though there will be brief lectures contextualizing each film's production and reception history, the majority of our meeting times will be spent on student-led discussion. Assignments include weekly written responses, a final project, and classroom participation. Because of the nature of the course topic and the content of the films, participation requires extended engagement with fictional depictions of issues including, but not limited to, lynching, sexual violence, police brutality, homophobia, and intraracial antagonism. Students are free to contact me at any point in the term if this becomes an issue.

79-239 History of the American Working Class

Intermittent: 9 units

This course will examine the transformation of the American working class from its preindustrial origins to the recent period of deindustrialization, gentrification, and the onset of the Corona Virus. It will emphasize the changing relationship between owners, managers, and workers, the role of the state, and the impact of gender, race, and ethnicity. More specifically, this course will not only analyze the factors that facilitated and/or impeded working class solidarity, but assess the impact of the working class upon the development of American history, including the recent recognition of previously maligned human service workers as "essential workers" during the upheaval of COVID-19.

79-240 Development of American Culture

Intermittent: 9 units

This is an introductory survey of American history from colonial times to the present. The course focuses on cultural history instead of the more traditional emphasis on presidents, wars, and memorizing facts or timelines. The major theme of the course is the changing meaning of freedom over three centuries. Required readings include several short books and historical documents, which will be paired with class lectures to provide students with context needed to think about and understand America's cultural history. Assignments will include three short essays and a final research project on a form of popular culture of the student's choosing, developed over the course of the semester through three short blog posts.

79-241 African American History: Africa to the Civil War

Intermittent: 9 units

The African American experience had deep roots in the rapid globalization of the world's people during the transatlantic slave trade. Like people of European, Asian, and Latino/Latina descent, Africans were part of the early Great Migrations of people from the Old World to the New. Unlike other ethnic and nationality groups, however, African people arrived in chains and swiftly acquired the legal status of "slaves for life." Was their enslavement inevitable? Was their transformation into commodities complete? Were they able to form viable families, communities, and movements to topple the institution of human bondage? Did they find dependable white allies? Did they Africanize American culture, politics, and economics? How did some 500,000 of these African people become free (some significant property holders) before the Civil War? Focusing on the development of African and African American life from the beginning of the colonial era through the late antebellum years, this course will explore these and many other questions in the lives of the earliest generations of African people on American soil. Based upon a variety of assigned texts, primary and secondary sources, and lectures, students will become familiar with a wide range of intellectual debates in African American history; write a series of short analytical essays; and advance their own well-argued and well-documented analyses of major controversies in both popular and scholarly interpretations of early African and African American life in the United States.

79-242 African American History: Reconstruction to the Present

Intermittent: 9 units

This course explores changes in the African American experience from the end of the Civil War to the emerging era of Joe Biden and Kamala Harris. Through an examination of a wide range of scholarly and popular debates in African American life and history, this course will emphasize transformations in both inter- and intra-race relations; economic mobility as well as economic inequality; and forms of political engagement and grassroots movements for social change. We will explore these developments under the impact of the segregationist regime; the Great Migration; the rise of the urban-industrial working class; increasing residential segregation; growth and expansion of the middle class; and the florescence of the Modern Black Liberation Movement. Students will compare the dynamics of the contemporary Black Lives Matter Movement with earlier 20th century grassroots social and political movements in African American and U.S. history. Finally, based upon a mix of primary and secondary sources and lectures, students will write a series of short analytical essays; and establish their own unique interpretation of key issues in Black History.

79-243 The Civil War in American Memory

Intermittent: 6 units

The American Civil War remains among the most venerated and fought over stories in American history. This class explores those debates. Why was the war fought? Was the Confederate cause noble? Did the North oppose slavery? What did freedom mean? How does a nation erect racial justice? What does it mean to fly the Confederate flag or confront a Confederate monument today? Tackling these ongoing debates (and more) from the war (1861-65) itself until today, this course grapples with why the war continues to be one of the most defining moments in U.S. history - 150 years later - and what that means for our past and present as a bi-racial democracy. This course is open to all students.

79-244 Women in American History

Intermittent: 9 units

This course is a survey. It examines U.S. history through the eyes of women and gender. It begins in the colonial era (1600s) and runs chronologically to the present. It covers topics such as witchcraft, the story of Pocahontas, women's work, motherhood, slavery, and much more. We will look at the lives of individual women, as well as trends among women, paying attention to questions of race and class. At the same time, we will explore changing concepts of gender, meaning ideas about what women are or should be. Finally, the course asks: how different does American history look when we factor in women and gender?

79-245 Capitalism and Individualism in American Culture

Intermittent: 9 units

This small discussion course traces ideas about individualism and capitalism in the U.S., from colonial times to the present. We will focus on three main themes: 1) the relationship between capitalism, work, and identity; 2) changing definitions of success and failure; and 3) the historical origins of students' attitudes toward 1 and 2. In short, we will study the economics and emotions of the American dream: how class, race, gender, occupation, and ambition shape our identities. Readings include "The Autobiography of Benjamin Franklin," poems by the enslaved writer Phillis Wheatley, studies by Alexis de Tocqueville and Max Weber, writings of Frederick Douglass, Henry David Thoreau, Charlotte Perkins Gilman, Andrew Carnegie's classic essay "Gospel of Wealth," an essay by Malcolm Gladwell, Arthur Miller's "Death of a Salesman," and Sarah Lewis's "The Rise," a book about failure and ambition. Grading is based upon a readings journal, participation in discussion, three short essays and a longer final paper.

79-246 Industrial America

Intermittent: 9 units

This course examines the transformation of America into an urban industrial society during the 19th and 20th centuries. The transformation of work, culture, and politics will receive close attention, but the course will primarily focus around how workers defined their own labor and changes in the culture of work over time. This course will investigate how race, class, and gender informed workplace relations as well as how immigration and migration changed the nature of American work. Through lecture, discussion, and three short writing assignments we will uncover how workers defined America.

79-247 African Americans, Imprisonment, and the Carceral State

Intermittent: 9 units

The mass incarceration of people of African descent has emerged as one of the most daunting issues in contemporary U.S. society and politics. But too often discussions of this important phenomenon proceed without sufficient historical perspective. Thus, this course explores the history of African Americans in the nation's prison system from the emancipation of some four million enslaved people following the Civil War through recent times. Specifically, we examine the process by which the nation's prison population shifted from predominantly white inmates during the mid-19th century through the inter-World War years to majority African Americans and other people of color by the closing years of the 20th century. In addition to examining the role of law, policing, and racist social policies and practices, students explore the lived experiences of imprisoned people, with an emphasis on the impact of class and gender as well as racial considerations. Along with selected primary documents, assigned readings include a series of scholarly case studies on the carceral experiences of black men and women in the North and South during the industrial and emerging postindustrial eras in African American and U.S. history. Finally, students will write a series of short essays on particular facets of African American life in the American prison system.

79-248 U.S. Constitution & the Presidency

Intermittent: 9 units

This course explores the changing role and powers of the American Presidency under the Constitution, from the founding era through the twentieth century. After absorbing drafting and ratification debates, we will focus on how particular presidents (Washington, Lincoln, FDR, Nixon) established or expanded the executive power and how particular conflicts (the Civil War, the "Court Packing" plan, Watergate) restructured or restricted the presidency. Readings will include the U.S. Constitution (of course), selections from The Federalist Papers, and short books including Daniel Farber's "Lincoln's Constitution" and Cass Sunstein's "Impeachment: A Citizen's Guide." Grades will be based on three short papers, a final paper, and daily preparedness and participation in group discussion.

79-249 20th Century U.S. History

Intermittent: 9 units

The twentieth century marked the rise of the United States as a global power. By the end of the century, the United States had achieved economic, military, and political dominance. The United States also made great strides in expanding political and civil rights for workers, women, African-Americans, and gays and lesbians. This course explores the cultural implications of these developments on the generations of American people who came of age in the twentieth century. It assesses both the triumphs and tribulations of twentieth-century life. We will analyze the continuities, contradictions, and conflicts in American history, especially in regard to the nation's dueling political ideologies: conservatism and liberalism. Special attention will be given to the evolving relationship among the state, the corporate sector, and ordinary people. Topics include: the Progressive Era, the Great Depression, World War II, the Cold War, Civil Rights, Vietnam, and the New Conservatism.

79-250 Voting Rights: An Introduction

Intermittent: 9 units

Did you know that American citizens have no right to vote? None. The United States is one of the only constitutional democracies in the world that does not enshrine this right in its founding charter. Not only did the nation's founders punt on creating one, social movements have also never succeeded in creating one. What, then, have voting rights activists won over the centuries? And how and why has an affirmative right to vote never been achieved? Starting with the U.S. Constitution and working forward to the present, this course will help you make sense of all the accusations swirling in the news about voter fraud, voter suppression, voter theft, voting rights, and all the other things no one ever taught you about the world's oldest democracy. This course is open to all students.

79-251 COVID-19: What History Can Teach Us

Intermittent: 3 units

For many, the COVID-19 Pandemic feels like a rupture in time - a disaster unprecedented in scale and impact. Yet one-hundred years ago, the Influenza Pandemic of 1918 killed between 17 million and 50 million people. That virus infected approximately a third of all human beings on the planet and #8212; some 500 million people. Since then, humanity has faced a series of influenza epidemics and other global catastrophes, from world wars to HIV-AIDS. Like COVID-19, those crises were shaped by pre-existing forms of inequality and discrimination based on race, gender, sexuality, religion, nationality, and other forms of identity. Pandemics affect everyone, but not equally. For many of the world's poorest and most oppressed people, the COVID-19 pandemic feels less like a rupture than an escalation of long-standing inequalities. In the United States, the racial disparities of the pandemic reflect the long history of systemic racism. How can we learn from the past about how to cope with our current crisis? How can we confront the inequities and injustices of the world in the midst of such a crisis? This course will offer a historical lens on many of the most urgent and difficult questions that we face as a result of COVID-19.

79-252 "Harriet": Harriet Tubman, Slavery, and the Underground Railroad

Intermittent: 6 units

Most Americans who know and love Harriet Tubman know she escaped enslavement, led herself and more than 60 people out of bondage via the Underground Railroad, gave instructions on getting to freedom to 50 or 60 more people, and became a suffragist. However, the many biographies, children's books, and even the biopic "Harriet" about Tubman are all virtually silent on a very important chapter of her life: during the US Civil War, Harriet Tubman worked as a nurse, cook, spy, and scout for the US Army Department of the South. This course will look at two parts of Tubman's life, her enslavement in the Maryland Eastern Shore and freedom via the Underground Railroad, as well as her military service in coastal South Carolina and participation in the Combahee River Raid, which freed 756 blacks enslaved on nine rice plantations six months after the Emancipation Proclamation went into effect. We will watch the biopic "Harriet" and discuss where it does and does not accord with historical sources about Tubman's life. And, we will tour the "From Slavery to Freedom" exhibit at the Senator John Heinz History Center to learn more about the Underground Railroad, particularly in Western Pennsylvania.

79-253 Imperialism and Decolonization in South Asia

Intermittent: 9 units

Home to a diversity of cultures, languages, and histories, the population of South Asia is linked through a common experience of European colonialism in the nineteenth and early twentieth centuries. Virtually all of the contemporary nation-states of South Asia achieved independence from European colonial powers in the middle of the twentieth century, most between the 1940s and 1960s. With a focus on South Asian history, this course will include introductory sessions on pre-colonial interaction and the early modern world. The bulk of the course will focus on colonialism, nationalism, and decolonization from the early nineteenth century to the mid-twentieth century. In addition to assessing the legacies of colonialism in the present day, the course will interrogate the differences between colonial and postcolonial experiences across the South Asian world. It will further examine the challenges and trials confronting the new states "after" decolonization, in particular, their search not only for new political frameworks to replace the colonial structures they had discarded, but also for solutions to mitigate the issues of social integration, inter-state conflict and regional co-operation.

79-256 Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990

Intermittent: 9 units

Between 1960 and 1990, young Europeans rebelled against the conservatism of their parents and politicians. In 1968, they exploded into the streets in capitalist Paris and socialist Prague. In West Germany and Italy, a minority of left-wing radicals took up the gun to bring former Nazis and Fascists to "justice." Young people demanded and practiced sexual liberation. Young women marched for their emancipation and led the struggle to legalize abortion. Young Europeans also contributed to the liberalization of anti-homosexual laws. The British Beat revolution rocked the world with its innovative music, anti-establishment lyrics, shocking fashions, and wild lifestyles. By the 1980s, youth rebellion had taken on disturbing trends with the emergence of right-wing Skinheads and a surge in drug addiction. The course combines lecture and discussion of readings and films. Students will write three essays (1000 words each) based on class assignments. They will write a final essay (1500-1700 words) based on their own research into the press, fanzines, films, etc. (in place of a final exam).

79-257 Germany and the Second World War

Intermittent: 9 units

This course examines the Second World War from the perspective of the country that was central to it in every way. The course will cover: Hitler's ideology, war plans, and military strategy; the military/technological history of the War in Europe and North Africa; the role of the SS; the Holocaust; the occupation of Europe and Resistance movements; the political, social, and economic history of the Third Reich, including popular opinion, the German Resistance, and the use of slave labor in factories and on farms. Readings will include historical studies, a novel, and a memoir/diary.

79-259 Black Rice

Intermittent: 6 units

Rice originates in only two places in the world: Africa and Asia. Most historians agree that West African rice and its cultivation and processing technology were transmitted to colonial SC and GA via the trans-Atlantic slave trade, laying the foundation for the commercial rice industry and making South Carolina rice planters the richest planters in British North America before the American Revolution. Though some historians don't agree.... In "Black Rice," we'll learn about how rice technology in West Africa's Upper Guinea Coast for subsistence, how it was transferred to the antebellum US South, and why technology in precolonial West Africa and enslaved people as skilled, not just brute labor are so, so controversial! In addition, we will watch the March 3, 2023 performance of "Unburied; Unmourned, Unmarked: Requiem for Rice" by the New York Philharmonic at Lincoln Center and discuss the libretto on which the project was based.

79-260 Nazi Germany

Intermittent: 9 units

This course covers Nazism in Germany from its beginnings as a small movement after the First World War through its rise to power in 1933 to its fiery destruction and defeat in 1945. What were the sources of its appeal as a political party? How did the Nazi regime suppress the political opposition in 1933? Why did so many ordinary Germans collaborate with the regime in its hunt against political, religious, sexual, and racial enemies? Why did they support the regime to the bloody end of the most murderous war in history?

79-261 The Last Emperors: Chinese History and Society, 1600-1900

Intermittent: 9 units

This course is an introduction to late-imperial "Chinese" history and society with a focus on the Qing dynasty (1644-1912). We begin by examining the Qing not just as the last of China's imperial dynasties but also as an early-modern, multi-ethnic empire that included Mongolia, Tibet, and Xinjiang. In fact, China's "last emperors" were actually Manchus from northeast Asia. Secondly we investigate the social, economic, intellectual and demographic developments that transformed late-imperial China prior to the coming of the West. Thirdly, we examine Qing responses to a string of nineteenth-century disruptions, including but not limited to western imperialism, that threatened to not only end the dynasty but also challenged the very tenants of Chinese civilization. Lastly, we will look at the fall of China's imperial system, the end of empire, and the post-imperial struggle to reformulate the state and re-imagine society for the twentieth century.

79-262 Modern China: From the Birth of Mao ... to Now

Intermittent: 9 units

This course is an introduction to major themes in twentieth-century Chinese history, including the transition from empire to nation, revolution, social change and modernization, western and Japanese imperialism, the rise of the party-state, Chinese socialism, economic liberalization and the so-called "Chinese Dream." The first half of the class is devoted to the period between the fall of the imperial system and the founding of the People's Republic of China (1911-1949). If the victory of the Chinese Communist Party and development of the socialist state are to be considered in historical context, it is necessary to first understand the political, cultural, economic and intellectual currents that immediately preceded them. During the second half of the course, we will examine the Maoist period (1949-1976). We will investigate the Chinese Communist Party as both a state-building institution and an engine of social transformation, and consider the tensions these dual roles produced. Finally, we will look at the Reform Period (1978-present), and reflect on a newly robust China's attempts to come to terms with its own recent past and what the consequences might be for both China and the world.

79-263 Mao and the Chinese Cultural Revolution

Intermittent: 9 units

This course is an in-depth examination of China's "Great Proletarian Cultural Revolution" (1966-1976), one of the most impactful and bewildering events of the twentieth century. It started when Mao Zedong announced that enemies had infiltrated the Communist Party that he led. Soon students were attacking their teachers, teenagers in army uniforms were raiding homes and destroying remnants of "feudal" and "bourgeois" culture, and armed fighting had erupted among factions of ordinary Chinese people. Why? What were the political and social dynamics of Maoist China that propelled it along this violent trajectory? What was everyday life like during the Cultural Revolution, an event that could be both terrifying and empowering for those that lived through it? What were the social, political and cultural consequences? How has the Cultural Revolution been judged in China and the west, and are there other possible interpretations? This class will explore these questions from a variety of perspectives and sources, including documents, literature, memoir, film, academic writings, visual arts and performing arts.

79-264 Tibet and China: History and Propaganda

Intermittent: 9 units

This course is an introduction to the "Tibet Question," the dispute over whether Tibet should be part of China, an independent nation-state, or, as the current Dalai Lama now advocates, something in between. "History" often serves as the battleground on which competing visions of the nation are fought - who should be included and excluded, where "natural" boundaries begin and end. This almost always requires a process of simplification in which inconvenient details are forgotten or repurposed in the service of national agendas. The "Tibet Question" is a telling example. In this class, we investigate the historical relationship between "China" and "Tibet" from the 13th century through the present, and note the ways advocates on both sides of the "Tibet Question" have constructed historical narratives (propaganda) in support of their political positions. We will also discuss the prospects for a political solution and consider the lessons the "Tibet Question" may hold for understanding other outstanding "historical" disputes.

79-265 Russian History: Game of Thrones

Intermittent: 9 units

How are states built? How are empires forged? This course, beginning with the first settlements of tribal nomads in the ninth century and ending with the abolition of serfdom in 1861, surveys the grand 'game of thrones' in Russian history. It explores the building of a Russian Empire from the first princely kingdoms at murderous war with each other to the emergence of a strong state, headed by a tsar and centered in Moscow. Over the centuries, we make the acquaintance of Mongol marauders, greedy princes, and brave peasant rebels, as well as Ivan the Terrible, Peter the Great, and the long succession of reformers and reactionaries who occupied the Russian throne. Students will be challenged to think critically about social injustice and resistance, and the relationship between ethnicity, serfdom, land ownership, and empire.

79-266 Russian History and Revolutionary Socialism

Intermittent: 9 units

This course covers an epic set of events in Russian history beginning with the emancipation of the serfs in 1861 and ending with the death of Stalin in 1953. Spanning almost a century of upheaval and transformation, it examines the terrorist and populist movements against the tsar, the growth of urbanization and a new working class, the great general strike and revolution of 1905, the Russian revolution in 1917, and the Communist Party and its attempt to build a new socialist society amid the wreckage of the old. We will discuss the struggle for power within the Party in the 1920s, Stalin's triumph over his opponents, the wrenching processes of collectivization and industrialization, and the "Great Terror." The course will explore the Soviet role in World War II, the shattering losses, and the death of Stalin in 1953. This course meets the Gen Ed requirement for "Humanities"

79-267 The Soviet Union in World War II: Military, Political, and Social History

Intermittent: 9 units

On June 22, 1941, Hitler invaded the Soviet Union. German troops surrounded Leningrad in the longest running siege in modern history, reached the outskirts of Moscow, and slaughtered millions of Soviet civilians. Of the 6 million Jews murdered by the Nazis, almost 2 million were killed on Soviet soil. Over 26 million Soviet citizens died in the war. Eventually, the Red Army came back from defeat to free the occupied territories and drive Hitler and his army back to Berlin. Using history, film, poetry, veterans' accounts, documentaries, and journalism, this course surveys the great military battles as well as life in the occupied territories and on the home front. It highlights the rise of fascism, the Stalinist purges of the Red Army, and the Nazi massacres of the civilian population. Occasional film screenings may be required.

79-268 World War I: The Twentieth Century's First Catastrophe

Intermittent: 9 units

This course offers a comprehensive retrospective of the First World War in Europe. Guiding questions will be: How did a containable crisis between Austria-Hungary and Serbia become the most murderous war Europe had ever experienced? How did the war spill over into the Middle East? Why did the US enter the war? Why did every General Staff follow unimaginative military strategies that turned the war into a bloody horror for soldiers? How did the war affect women's situation and rights? How did the war become a Total War that fomented social and political revolution and led to the downfall of four Empires?

79-269 Russian History: From Socialism to Capitalism

Intermittent: 9 units

Beginning with Stalin's death in 1953, this course focuses on the efforts of a new group of Soviet leaders to eliminate the repression of the Stalin years and to create a more democratic socialism. It will examine the reforms of Khrushchev and the reaction against them, the long period of Brezhnev's rule, and the hopeful plans of Gorbachev. Finally, it will survey Gorbachev's loss of control, the collapse of socialism and the Soviet Union, and the growth of "wild west" or "gangster" capitalism. We will look at the rise of the oligarchs and the impact of the capitalist transition on ordinary people. The course provides essential background for anyone interested in understanding Russia's place in the world today and its relationship with the West.

79-270 Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present

Intermittent: 9 units

This course will examine the history of anti-Jewish hatred and violence from the Middle Ages through the present. The course will focus on representative case studies, texts, and films. These will include pre-modern incidents of "fake news" such as the medieval rumor of "blood libel" that unleashed massacres and mass expulsions of Jews from countless communities. In examining the rise of modern anti-Semitism, we shall focus on debates over Jewish assimilation and citizenship and consider the popular impact of the print media's dissemination of conspiracy theories of Jewish world domination, including the infamous forgery, "The Protocols of the Elders of Zion." We will also examine cases of mass anti-Jewish violence, known as pogroms, in Eastern Europe and Russia, and the genocidal onslaught against European Jewry by the National Socialist regime. Finally, we will discuss the contemporary global resurgence of anti-Semitism.

79-272 Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal

Intermittent: 9 units

In Medieval Spain and Portugal, Islam, Judaism and Christianity coexisted in a situation distinguished by cooperation and exchange, as well as by friction, rivalry and violence. In this course, we shall explore the complexity of this unique historical encounter, as well as its role in shaping debates over modern Iberian and global identities, and historical memory. We shall discuss topics such as: Inter-ethnic collaboration and violence; Jewish-Christian disputations; the exclusion and expulsion of religious and ethnic minorities; as well as Muslim and Jewish presence in present day Spain and Portugal. Historical documents, literary texts, film, musical traditions, as well as contemporary political and cultural debates will be discussed to enhance familiarity with the topic.

79-273 Jews and Muslims in History

Intermittent: 9 units

What is the history of Muslim-Jewish interaction beyond the Palestinian-Israeli conflict and the images of violence in the Middle East that permeate the media? The overarching goal of this course is to explore this question through close study of the history of Jews and Muslims who lived as neighbors, in cooperation as well as in conflict in the Middle East, North Africa and Europe, from the rise of Islam in the seventh century to the present day. Our sources will include works of scholarship, primary source texts such as religious queries and government documents, journalistic materials, memoirs, and films.

79-275 Introduction to Global Studies

Spring: 9 units

We live in an increasingly interconnected world, one in which our everyday actions have repercussions across vast distances. To understand this ever-denser web of connections, we must think beyond simplistic accounts of globalization as a uniformly positive, negative, or homogenizing process. Economic crisis, impoverishment, rising inequality, environmental degradation, pandemic disease, and irredentist movements are just as much a part of the story as are technological innovation, digital communication, global supply chains, cultural exchange, the promotion of human rights, and the rise of cosmopolitan values. This course aims to equip you with an interdisciplinary toolkit for thinking critically about the many dimensions of globalization (economic, social, political, cultural) and for engaging thoughtfully with differing experiences of them. By examining how globalization connects and shapes the everyday lives of people around the world, including our own, we will establish a foundation both for your advanced coursework in Global Studies and for your lifelong education as a globally aware professional and citizen.

79-276 Beyond the Border

Intermittent: 9 units

In this course we will consider the historical emergence and transformation of the U.S.-Mexico border, as much as an idea as a physical boundary. Our explorations will be far-ranging: from the initial encounters of Christopher Columbus and Hern and Cort and Cort with indigenous populations, to social, cultural and political dynamics of the borderlands in subsequent centuries; from the experiences and practices of cross border migrants, to contemporary immigration debates and policies surrounding migration, border control and walling, and the deportation of unauthorized migrants. In addition to course readings, we will screen several Mexican films that are centrally concerned with the dynamics of bordering and border-crossing

79-278 How (Not) to Change the World

Intermittent: 9 units

It's often said that the road to hell is paved with good intentions. What, then, can we learn by excavating some of those pavers and interrogating the theories of change that underlie them? And what can we learn from more successful attempts to enact social change? In this course, we will use the tools of history, anthropology, and critical theory to examine various efforts to 'change the world'. From top-down social engineering to neoliberal 'market citizenship' to grassroots organizing, case studies will challenge us to detect theories of change (even when they are concealed) and evaluate their consequences (intended and otherwise). With those lessons in mind, we will then apply our tools to the theories of change that we enact, often unwittingly, as members of a university. Which roads are we paving and where do they lead?

79-280 Coffee and Capitalism

Intermittent: 9 units

What role has coffee played in connecting people and places to capitalist markets and consumer cultures? What are the economic, social, and environmental consequences of these connections? How did espresso change from an "ethnic drink" to something served at McDonalds? Why do college students (and professors!) hang out in coffee shops? This course will answer these questions and more by using coffee to learn about the history of capitalism, and capitalism to understand the history of coffee. We will follow the spread of coffee and capitalism across the globe, with excursions to places where people grow coffee (Ethiopia, Yemen, Indonesia, Brazil, and Costa Rica), and also where they drink coffee (Seattle, Tokyo, Seoul, New York, and Berlin). In the process, we will confront global problems linked to economic inequality, trade, gender relations, and environmental degradation. Course meetings will combine interactive lecture, group discussions, and mini-presentations. Assignments will include journal responses, ethnographic observations, and writing a short script that tells a story about coffee and capitalism.

79-281 Introduction to Religion

Intermittent: 9 units

Religion can be understood from the "outside," through the academic lenses of history, sociology, psychology, philosophy, etc., and from the "inside," listening to the experiences and reflections of those who practice various faiths. The course will examine major religious traditions from several perspectives and begin to explore such topics as the relationship between religion and science, faith and reason, religion and moral values, and religion in public life. This introduction is designed for students with a general interest in religion, as well as those contemplating a Religious Studies minor.

79-282 Europe and the World Since 1800

Intermittent: 9 units

This course will introduce students to topics of historical and contemporary relevance in European society and culture from the nineteenth century to the present. We shall focus especially on Europe's place in shaping debates of major international importance and #8212;both new and old and #8212;about topics such as: colonialism; migration; religious, ethnic, and national identity; Islamophobia; and antisemitism. Throughout we will pay special attention to the situation of inhabitants, past and the present, who have been considered outsiders or "others" in European society. In addition to class lectures, students will view films and listen to music related to the main themes of the course, in addition to reading and discussing historical texts.

79-283 Hungry World: Food and Famine in Global Perspective

Intermittent: 9 units

The science and technology of the Green Revolution in the second half of the 20th century were heralded as a miracle. Agricultural science promised seeds, peasants, companies, governments, scientists, economists, exporters, and planners would work together to support growing populations, especially in the post-colonial world. The human population on Earth reached 6 billion by the year 2000; 7.6 billion were estimated around 2017. The United Nations predicts 8.6 billion by 2030. Awareness of living in this unique period of human history brought new debates among scholars, practitioners, and planners thinking about the critical role of agriculture and development on Earth. How can we conceptualize, hope, and plan for best possible outcomes for a human population that depends on agriculture and development? How has the legacy of the Green Revolution encouraged (or betrayed) public enthusiasm for innovative fixes? This interdisciplinary course will use methods and case studies drawing on History, Historical Demography, Anthropology, Cultural Studies, Regional Studies, Geosciences and Agricultural Sciences, and International Economic Development. If students wish to pursue a particular thematic or regional interest, there will be room in this course to explore particular cases in depth.

79-288 Bananas, Baseball, and Borders: Latin America and the United States

Intermittent: 9 units

This course will examine the tumultuous and paradoxical relationship between Latin America and the United States from the time of independence to the present, with an emphasis on Mexico, Central America, and the Caribbean during the Cold War (1945-1989) and its aftermath (1990s-present). We will literally talk about bananas, baseball and borders; the title also alludes to the key dimensions of the relationship we will study: economic, cultural, and geopolitical. We will learn about the actions of U.S. and Latin American government leaders and diplomats along with many other kinds of people including activists, artists, and journalists; athletes, movie stars, and scientists; and migrant workers, tourists, and drug traffickers. Mondays and Wednesdays will feature interactive lectures, videos and in-class activities; Fridays will be entirely devoted to student-driven discussion. Evaluation will be based on participation; two written analysis of historical documents, and a final reflection.

79-289 Animal Planet: An Environmental History of People and Animals

Intermittent: 9 units

Why do modern societies go to great lengths to protect some animals and slaughter others? Why do some cultures make pets of animals that other cultures turn into a meal? What are the environmental ramifications of hunting, domestication, and trading animals? Is there a connection between human pandemics like COVID-19 and animals? Why are there so many cute animals inhabiting social media? These are some of the questions that we will seek to answer as we trace changes in human and #8212;animal relationships over time. We will explore these themes through both texts and visual representations (art, film, photography) of animals. Evaluation will be based on active participation in class discussions, submission of weekly field notes, and a final curated exhibit of images of people and animals.

79-290 The Slave Passage: From West Africa to the Americas

Intermittent: 9 units

"The Slave Passage" begins among flourishing, technologically advanced, and globally connected regions of Western Africa before the advent of the trans-Atlantic slave trade. It tells the painful story of African captives during the Middle Passage, piecing together the historical record to recognize their suffering aboard the slaving vessels and their multiple strategies of resistance. Students will study slave narratives, slave ship logs, and autobiographies of former enslaved people, as well as analyze films depicting the Middle Passage and New World enslavement.

79-292 The Ends of the Earth: An Ecological History of Deserts

Intermittent: 9 units

The course will examine ways in which visitors to desert climates and landscapes write about their experiences in relation to the experiences and lifestyles of communities that reside in the desert on a regular basis.

79-293 Inward Odyssey

Intermittent: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. Inward Odyssey will explore world history by examining it through the outward-looking eyes of travel writers, on the assumption that travelogues, though supposedly written about the "other," in fact provide crucial insights about the mindset of the culture that produced them, and often serve as a vehicle for cultural self-exploration or even self-criticism. In terms of content, this course is intended to overlap with World History, Islam and the European World, and US-Arab Encounters. However, this course is intended to be a skills course, designed not to teach students about specific historical periods, but rather to give students the tools they need to conduct their own critical explorations into the historical past.

79-295 Legacies of Fascism and Anti-Fascism: From 1930s Spain to Russia's War on Ukraine

Intermittent: 3 units

Russia's war on Ukraine has elicited divergent responses from different political and civil actors and scholars around the globe. Many of these responses are steeped in the history of the 1930s and World War II, including around questions of fascism and anti-fascism. In this course we will inquire whether the history of fascism and anti-fascism might provide us with any useful tools to address the current war in Ukraine. We will start by examining the history of the rise of fascism and of antifascist response, beginning with Mussolini's march on Rome in 1922 and the impact of Italian fascism on Spanish fascism and the outbreak of the Spanish Civil War (1936-1939). The final part of the course will focus on the origins of the war in Ukraine. We will hear from guest speakers, including relatives of volunteers and experts on the Spanish Civil War, as well as experts on the history of Ukraine, including Ukrainian scholars and refugees. Monday, 10/31 from 4:40pm-7:00pm-HH B131 Tuesday, 11/1 from 4:40pm-7:00pm-HH B131 Wednesday, 11/2 from 4:40pm-7:00pm-HH B131 Thursday, 11/3 from 4:40pm-7:00pm-HH B131 Saturday, 11/5 from 11:30am-5:00pm-BH A36

79-296 Religion in American Politics

Intermittent: 6 units

Religion figures prominently in American politics, especially in congressional election years. A common view, reinforced by some media and polling organizations, holds that "religiosity" correlates with conservative politics, but that's highly misleading, as religious people are in fact all over the political map - even on issues like abortion, same-sex marriage, and what is taught in public schools. Thomas Jefferson's mention of a "wall of separation" between church and state indicates that religious institutions are generally kept separate from government in America, but religious motivations have always played an important part in our politics. This course will provide a historical perspective on religion in public life down to the present day, including religion's influence on political parties and public policies, and the boundaries set by the Constitution on such activity.

79-297 Technology and Work

Intermittent: 9 units

In recent years, conversations about the relationship between technology and work seem to have been conducted with particular fervor: claims of revolutionary ease and freedom sit side-by-side with dystopian visions of exploitation, surveillance, and alienation. Will technological development lead to a new "sharing economy" or widespread deskilling? Will it bring general prosperity or enrich the few at the expense of the many? These concerns - though especially apparent today - are by no means new. In this course, we will examine their history, focusing in particular on North America and Europe in the past two centuries. We will examine the ways in which new technologies - from the assembly line to the washing machine to the personal computer - transformed what it meant to work, and how workers, their families, and the companies who employed them reacted to these changes. Our historical actors will include famous figures like Henry Ford, but also unnamed women, children, people with disabilities, and racial and ethnic minorities. Throughout, we will pay attention to who benefitted, who was harmed, and what broader economic, cultural, or social purposes these technologies were designed to serve.

79-298 Guns, Gun Cultures, and Gun Violence in American History

Intermittent: 6 units

This course traces the development of gun cultures and gun-related policy and law in the United States from the colonial era to the present. Students will be expected to synthesize perspectives from social history, ethnography, public health, criminology, policy analysis, and legal scholarship. They will also engage the critical examination of popular culture and media representations of guns and gun violence. Particular emphasis will be placed on changing views about the authority of the government to intervene in the manufacture, ownership, and use of guns, as well as the best way to balance individual and collective interests in a pluralistic society.

79-300 History of American Public Policy

Intermittent: 9 units

This course traces the development of US domestic public policy, the growth of the federal government, and the changing relationship among citizens, states, and the federal government over time. We begin with an examination of the current policy landscape and then go back in time to understand how we got to where we are today. We very quickly discover that our current political predicaments are not accidental. Particular people or groups across the political spectrum have worked hard to shape public policy at various critical points in history and have reaped tremendous benefit, even if their influence makes the overall system unstable or unworkable today. We identify critical moments of crisis or change in American politics, examine the imaginaries and policy levers available to people at that time, and explain how policy decisions were made. Students will gain a clear understanding of how interests and political will have been cultivated and mobilized in the past, which can offer them useful models for advancing their own priorities and those of their generation. Topics covered currently include health care and health insurance, abortion, and immigration.

79-301 History of Surveillance: From the Plantation to Data Capitalism

Intermittent: 6 units

Our awareness of surveillance has been dramatically heightened over the past few years. From Edward Snowden's revelations about the U.S. National Security Agency's data collection infrastructure to the extent to which companies like Facebook and Google monetize our personal information, surveillance has become one of the most controversial political issues of our time. In this course, we will place these developments in context, examining the long history of surveillance in the United States. We will begin with the 18th-century plantation "overseer," who was charged with ensuring the productivity and obedience of slaves under his watch. We will then move on to explore the emergence of commercial surveillance in the 19th century, which sought to gather intelligence on the credit worthiness and moral worthiness of businessmen in a rapidly growing, and increasingly impersonal, economy. Next, we will examine the shifting focus of surveillance from the late 19th century to the present, as it expanded from immigrants and criminals to include industrial workers, political radicals, civil rights activists (most notably Martin Luther King), the poor, and ultimately, all of us. Today, anyone who has a cell phone in their pocket, surfs the Internet, keeps up with friends through social networks, makes purchases with a credit card, uses membership cards, travels, or even just spends time in public spaces ought to assume that their movements, purchasing habits, communication metadata, social connections, and Internet browsing histories are being recorded, stored and analyzed for a variety of governmental and commercial purposes. In the final week of the course, we will debate the implications of these incursions into our public and private lives.

79-302 Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems

Intermittent: 9 units

Unmanned aerial vehicles (drones) have become a central feature of the United States' global counterterrorism strategy since September 11, 2001, and autonomous weapons systems (often called "killer robots" by critics) are increasingly being integrated into military arsenals around the world. According to proponents, drones and autonomous weapons systems are much safer than manned systems, so accurate that they can be used to target individuals and detect threats in real time, and efficient and inexpensive enough to be used for long-term surveillance and protection missions around the globe. According to critics, the use of lethal autonomous weapons systems is problematic because of the obfuscation of historically and legally accepted chains of accountability and responsibility, as well as the difficulty of translating complex decision-making processes including ethical and moral ones into computer code. This course will evaluate these issues through the lenses of law, politics, morality, history, and military strategy.

79-303 Pittsburgh and the Transformation of Modern Urban America

Intermittent: 6 units

This course will focus on the transformations, both positive and negative, of Pittsburgh and the Pittsburgh region in the period from 1945 through the present. It will explore the following themes: the rise of industrial Pittsburgh, the redevelopment of the city in the Pittsburgh Renaissance; urban renewal and its consequences; the collapse of the steel industry and its impacts; the development of an Eds/Meds service economy; air, land and water environmental issues; and the city's changing demography.

79-304 African Americans in Pittsburgh

Intermittent: 6 units

This course will examine the development of Pittsburgh's African American community from the Great Depression and World War II through the era of deindustrialization during the late 20th and early 21st centuries. The course will emphasize not only the ways that a variety of external socioeconomic, cultural, and political forces shaped the history of black people in western Pennsylvania, but also the diverse strategies that African Americans devised to give meaning to their own lives and how these changed over time. Students will read both primary and secondary accounts of Pittsburgh's African American history; write short analytical papers on specific topics or themes; and engage in regular classroom discussions of assigned readings.

79-306 Fact into Film: Translating History into Cinema

Intermittent: 9 units

From the very beginning, film has provided a window into the past. But how useful are the images we see through that window? For every person who reads a work of history, thousands will see a film on the same subject. But who will learn more? Can written history and filmed history perform the same tasks? Should we expect them to do so? How are these two historical forms related? How can they complement each other? This course will draw examples from across the history of film in order to examine how the medium of film impacts our understanding of facts and events, the ways that film transfers those facts to the screen, and how that process affects the creation of historical discourse. Films may include such titles as *The Fall of the Roman Empire*, *The Gunfight at the O.K. Corral*, *Saving Private Ryan*, *World Trade Center*, *Enemy at the Gates*, *Lagaan* and *Hero*.

79-308 Crime and Justice in American Film

Intermittent: 9 units

Films dealing with criminal activities and criminal justice have always been popular at the box office. From the gangsters of the Thirties and the film noir of the Fifties to the more recent vigilante avenger films of Liam Neeson, the film industry has profited from films about crime and its consequences. How those subjects are portrayed, however, tells us a great deal about larger trends in American history and society. Every imaginable type of criminal activity has been depicted on screen, as have the legal ramifications of those acts. But these films raise profound questions. What is the nature of crime? What makes a criminal? Are there circumstances in which crime is justified? How do socioeconomic conditions affect the consequences? How fair and impartial is our justice system? Perhaps most importantly, how do depictions of crime and justice in popular media influence our answers to these questions? This class will utilize a variety of films to discuss the ways in which popular media portrays the sources of crime, the nature of criminals, the court and prison systems, and particular kinds of criminal acts. Films to be screened may include such titles as *The Ox-Bow Incident*, *Out of the Past*, *12 Angry Men*, *Young Mr. Lincoln*, *Brute Force*, *The Equalizer*, *Jack Reacher* and *Minority Report*. By thoroughly discussing these films and related readings we will be able to trace the various changes in attitude towards crime and justice in America over the last century.

79-309 The Chinese Revolution Through Film (1949-2000)

Intermittent: 9 units

This course is about both film and history. It is not a detailed history of film, but rather introduces some key issues of modern Chinese history and examines how that history is treated in film. Most of the films are made in China (including Taiwan and Hong Kong) but some are produced in the west. Topics that may be explored include the rise of the Communist Party, life in Maoist China, the Cultural Revolution, the Cold War/anti-imperialism, depictions of China's minority peoples, and the Reform-era under Mao's successors. Along with feature movies, we may view documentaries, propaganda films, TV shows and even music videos. In addition to providing a general history of the period, accompanying readings and assignments explore the social context and methodology of the films while developing critical skills in writing, analysis, and historical imagination.

79-312 War and Peace: A History of Peace Movements

Intermittent: 9 units

We generally assume war is a constant in our history and in the modern world. However, in every era there have been voices attempting to understand, explain and ultimately prevent it. In the modern world there has been a great deal of debate about the relationship of violence, capitalism, colonialism, empire, and racism to war. We will examine some of these debates among peace activists. Advocates for peace have attempted to build movements addressing the factors leading to war. What kinds of efforts have been made for a more peaceful world and how have they fared? We will examine how world leaders, business people, civil rights, and other peace activists have thought about war and peace. We will examine case studies of select wars and select peace movements.

79-313 "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration

Intermittent: 6 units

What is home? What does it mean to belong? What does it mean to be mobile? Is mobility a privilege or a curse? How do experiences of migration, exile, and displacement shift one's understanding of home? This course examines the modern patterns of mobility and displacement, with a focus on the US and Europe at particular moments during the 19th, the 20th, and 21st centuries. We will focus on several case studies to illustrate broader concepts: the connection between the formation of nation-states and the rise of exclusionary citizenship; the emergence of 20th-century modern legal concepts such as "refugee" and "asylum"; the influence of the Cold War on the immigration policies in the US; and the criminalization of border-crossing.

79-314 How Do We Remember? The Politics and Cultures of Memory

Intermittent: 9 units

What is the relationship between an individual person and collective memories? How do societies "remember"? This course proposes an interdisciplinary approach to the relationship between memory and history. It explores various ways in which societies have mobilized their remembrances of the past for political and economic ends in the present; how and whose memory began to matter in a global 20th century; and how individual testimonies have highlighted the role of body, experience, trauma, and nostalgia for writing new, more inclusive and heterogenous histories. In the first part of the course, we will read excerpts from works by historians, sociologists, and anthropologists about cultural and collective memory. In the second part of the course, we will analyze how the politics of memory intermesh at a local and global scale, via a set of case studies that focus on: the memory of the Shoah (the Holocaust) in post-1945 Western and Central Europe; political violence, civil war, and reconciliation in post-1990 Guatemala; and the role of remembrance and testimony for claims of moral retribution in the aftermaths of colonialism (the Mau Mau revolt in colonial Kenya and the long-term efforts of the British government to conceal their violent repression of the anticolonial struggles). This class will follow the format of a seminar. The professor will give short lectures each week in order to introduce the readings and place them within larger debates, but the course will mainly be discussion-oriented.

79-315 Thirsty Planet: The Politics of Water in Global Perspective

Intermittent: 9 units

Water is necessary for all forms of life on Earth. The purpose of this course is to introduce students to social and political aspects of water, using in-depth case studies that draw on a variety of perspectives. Examples of regional water projects we'll study include traditional tank irrigation in South India; international negotiations along the Nile River; and the U.S. Government in negotiation with native activists and fisheries on the Columbia River. In addition to regional variety, readings will explore a variety of themes, for example, water and gender; water and armed conflict; and water and private companies versus public management. By the end of this course, students should be able to articulate their own answers to these questions: How have global organizations and participants characterized, enacted, and addressed problems of water supply and delivery for those who need it most? How do particular regions reflect global trends in water resource development, and how might these diverge from global trends? How have social and environmental studies in the literature of development come to understand the problem of water? One set of readings is assigned each week. Students should be prepared to discuss each week's readings in a thoughtful way during class meeting time.

79-316 Photography, the First 100 Years, 1839-1939

Intermittent: 9 units

Photography was announced to the world almost simultaneously in 1839, first in France and then a few months later in England. Accurate "likenesses" of people were available to the masses, and soon reproducible images of faraway places were intriguing to all. This course will explore the earliest image-makers Daguerre and Fox Talbot, the Civil War photographs organized by Mathew Brady, the introduction in 1888 of the Kodak by George Eastman, the critically important social documentary photography of Jacob Riis and his successor, Lewis Hine, the Photo-Secession of Alfred Stieglitz, the Harlem Renaissance of James VanDerZee, the precisionist f64 photographers Ansel Adams, Imogen Cunningham, and Edward Weston, and other important photographers who came before World War II. The class will be introduced to 19th century processes, such as the daguerreotype, tintype, and ambrotype, as well as albumen prints, cyanotypes, and more.

79-317 Art, Anthropology, and Empire

Intermittent: 9 units

This seminar will explore the anthropology and history of aesthetic objects, as they travel from people and places sometimes labeled "primitive" or "exotic" to others, whose inhabitants deem themselves "civilized," "modern," or Western. First, we will consider twentieth-century anthropological attempts to develop ways of appreciating and understanding objects from other cultures and in the process to reconsider the meaning of such terms as "art" and "aesthetics." Then we will discuss several topics in the history of empire and exoticism. Finally, we will consider attempts by formerly colonized populations to reclaim objects from museums, and to organize new museums, aesthetic styles, and forms of artistic production that challenge imperialism's persistent legacies.

79-318 Sustainable Social Change: History and Practice

Intermittent: 9 units

If you wanted to change the world, who would you ask for guidance? Mahatma Gandhi? Rachel Carson? Nelson Mandela? In this interdisciplinary course, we will examine the history of efforts to create sustainable social change. Through a series of targeted case studies, we will examine the successes and failures of notable leaders, past and present, who strove to address social problems nonviolently and to create lasting improvements in fields such as education, healthcare, and human rights. In keeping with the example of the people we will be studying, we will bring our questions and our findings out of the classroom through a variety of creative, student-driven experiments in sustainable social change.

79-319 India Through Film

Intermittent: 6 units

Bollywood films attract hundreds of millions of viewers, not just in India but throughout the world. The name "Bollywood" makes it seem that the Indian film industry is a junior partner, merely an echo of Hollywood. But more films are made in Mumbai every year than in Los Angeles. And Mumbai is only one of many film hubs in India. The rich diversity of Indian cinema speaks to the equally rich history of India itself. This course uses Indian movies to examine several key themes in India's history. We will focus on the twentieth century and on questions of democracy, diversity, and development. This course includes a mandatory film screening on Wednesday evenings beginning at 6:30pm.

79-320 Women, Politics, and Protest

Intermittent: 9 units

This course examines the history of women's rights agitation in the United States from the early nineteenth-century to the present. It investigates both well-known struggles for women's equality and #8212;including the battles for women's voting rights, an Equal Rights Amendment, and access to birth control and #8212;and also explores the history of lesser-known struggles for economic and racial justice. Because women often differed about what the most important issues facing their sex were, this course explores not only the issues that have united women, but also those that have divided them, keeping intersectionality and women's diversity at the center of the course. This course is open to all students.

79-321 Documenting Human Rights

Intermittent: 9 units

This course will teach students about the origins of modern human rights and the evolution of methods to document the extent to which these rights are being upheld or violated. The need to understand and document human rights issues is at the center of the most pressing current events. From threats to democracy and civil rights to work holding perpetrators of mass harm accountable in legal proceedings to efforts to quantify and advance economic, social, cultural, and environmental rights, making human rights violations visible is fundamental to achieving a more just world. We will begin with an overview of the history of human rights, the main philosophical and political debates in the field, and the most relevant organizations, institutions, and agreements. We will then delve into specific cases that highlight methodological opportunities and challenges, including: the identification of mass atrocity victims, the disappeared, and missing migrants; efforts to estimate civilian casualties in war; the documentation of police brutality and other human rights violations with smartphones; as well as the use of satellite imagery and drone footage for the documentation of genocide, environmental rights, and war crimes. We will critically assess the technical challenges that arise in each context and how the human rights and scientific communities have responded. After reviewing these cases, we will conclude by reflection on why the documentation of human rights actually matters and what happens to evidence once it is gathered. Students will then take what they've learned and do two multidisciplinary group projects, one involving the document of a rights violation in Western Pennsylvania and the other involving an international situation. Assignments include an essay, a data analysis assignment, and a group project that include a written component, quantitative and/or qualitative data analysis, and a presentation.

79-322 Stalin and the Great Terror

Intermittent: 9 units

Joseph Stalin has been vilified and praised, damned and worshipped. He left behind a mixed and complex legacy. He created an industrialized modern economy in the Soviet Union and won a great and painful victory over the Nazis. At the same time, he built a police state, sent millions to labor camps, and destroyed the possibilities for socialist democracy. When he died, thousands of Soviet citizens wept at his funeral and the prisoners in the camps toasted his death. This course will examine Stalin, the man, and Stalinism, the phenomenon. Using history and film, we will explore one of the most complicated and influential dictatorships of the 20th century.

79-323 Making Modern Cities

Intermittent: 9 units

Cities have been a feature in the landscapes of human settlement for nearly 6000 years. This course will examine the origins and evolution of cities by examining the role of urban areas in the economic, cultural, political, and environmental history of the world. The main line of inquiry for this course emphasizes the culture of cities and the processes of urbanization that give rise to them. Students will explore why and how cities form, the functions they serve, the ways of life they support, and the problems and opportunities to which they give rise. Cities are socially and politically contested spaces, and observers of urban life have long-sought to understand the process of urbanization and the consequences of living in cities. Some argue that cities represent the crowning achievement of modernity; others suggest that cities are isolating and alienating, fostering discord, rather than social cohesion. The course integrates work by historians, urban planners, architects, political scientists, geographers, and sociologists to provide a comprehensive set of tools to understand and analyze modern urban life.

79-324 #MeToo: Naming and Resisting Gender Violence

Intermittent: 6 units

#metoo represents a sea change in society's response to gender-based violence. This course addresses gender-based violence as a public health and human rights issue, focusing on the U.S. and asking where we are, and how we got here. It will delineate the legal and social definitions of gender violence, explore how those definitions function both positively and negatively, and examine the long history of protest that has culminated in this moment. Come join the conversation! This course is open to all students.

79-325 U.S. Gay and Lesbian History

Intermittent: 6 units

US Gay and Lesbian History offers an overview of the changing context and circumstances of sexual minorities in American culture. From early constructions of moral opprobrium, criminal deviance or medical pathology, the LGBT community emerged in the twentieth and twenty-first century as a political constituency and a vital part of contemporary society. Students should be aware that this course will necessarily address issues of intimate relations and sexuality as well as broader historical issues.

79-326 Shall We Dance? Culture, Politics, and Movement in the 20th Century

Intermittent: 6 units

Waltzes and flash mobs, hula and swing, disco and breakdance: this course will examine the history and practice of these and other popular dance movements across the course of the twentieth century. In doing so, we will pay particular attention to the ways in which dance both shaped and reflected major moments of political, cultural, and social change. Dancing bodies were used to justify imperial ambitions, explore new kinds of gender relations, and both uphold and upend racial hierarchies, making dancers key - if underappreciated - participants in the century's tumultuous history. The course will include a mix of lecture and discussion, drawing on scholarly analyses, archival sources, films, literature, images, and live performances. Students will also be asked to explore at least one new dance form for themselves and reflect on the experience.

79-328 Photographers and Photography Since World War II

Intermittent: 9 units

Invented in 1839, photography was a form of visual expression that immediately attracted a large public following. Starting around 1900, photography was practiced with two dominant strands. One of these firmly believed in the power of photographs to provide a window on the world, and was led by Lewis Hine, whose documentary photographs for the National Child Labor Committee helped to ameliorate living and working conditions for thousands of immigrant children. The other strand adhered to the philosophy of Alfred Stieglitz who adamantly affirmed that photographs were first and foremost reflections of the soul and were art objects, equal to painting, drawing and sculpture. These two schools of thought guided photographers throughout the twentieth century. This course explores in depth the tremendous range of photographic expression since World War II and examines in particular the contributions of significant image-makers such as Helen Levitt, W. Eugene Smith, Robert Frank, Diane Arbus, Garry Winogrand, Charles "Teenie" Harris, Cindy Sherman, Carrie Mae Weems, Nan Goldin, James Nachtwey, and many others. Classes include a slide lecture, student presentation, and video segments that introduce a focused selection of images by major photographers in an attempt to understand their intentions, styles, and influences. As available, students will be expected to make one or more visits to photography exhibitions on view in Pittsburgh (locations to be announced at the first class.)

79-329 LGBTQ+ History

Intermittent: 9 units

This class introduces and discusses LGBTQ history over time, drawing cases and readings from a number of cultures and timeframes. It introduces students to the concept of sexuality as an area of historical inquiry as well as introducing students to the methods and the questions that have engaged historians in this area.

79-330 Medicine and Society: Health, Healers, and Hospitals

Intermittent: 9 units

How have notions of health and healing changed over time in the United States? Why are doctors seen as professional "heroes"? Why are hospitals so central to patient care and professional training? How has American healthcare developed into its present form? This course explores the history of American medicine and its relationship to American society. By exploring major developments in the history of American medicine and public health, students will examine the voices of historical actors, including physicians, patients, activists, policymakers, and researchers. In analyzing these voices, students will learn what was at stake as Americans confronted diseases and struggled to explain and cure them. Students will also examine medical research, education, disease patterns, patient experiences, and technologies from the colonial period to the present day. Readings include a range of primary accounts and secondary sources of medicine and health in America.

79-331 Body Politics: Women and Health in America

Intermittent: 9 units

[Note: Students who have taken 66-121, First Year Seminar: Body Politics: Women and Health in America, may not enroll.] This course takes a topical, intersectional approach to the history of U.S. women's health in the nineteenth and twentieth centuries. It is less about governmental politics, although we do some of that. Rather, it sees bodies as cultural texts through which power is built and contested. The course covers topics such as the history of anatomy, menstruation, reproductive rights, body image, mental health, sexuality, violence, childbirth, and menopause. We explore how science and American culture both have constructed these issues over time (some of it is super whacky!), while also examining women's organizing around them. This course is open to all students.

79-333 African Americans, Race, and the Fight for Reparations

Intermittent: 9 units

By the onset of the 21st century, African American history and interdisciplinary programs in Black studies had emerged at the center of our reinterpretation of the American experience. And with this new understanding of the nation's history there has been a growing interest in the relationship of history to public policy, race, human injustice, and resulting redress movements in comparative and historical perspective. Accordingly, this course will not only explore the case for reparations by analyzing the inequities of enslavement, Jim Crow, and post-industrial capitalism. It will examine the ongoing fight for reparations among people of African descent from the early postbellum years after the Civil War through the Black Lives Matter Movement in recent times. In addition to examining the experiences of Blacks in the United States, however, this course will consider other experiences around the globe: Native Americans, Mexican Americans, and Japanese Americans within the United States; the Holocaust in Germany; Japan's so-called "comfort women" system of sexual exploitation; and South Africa's movement toward reconciliation and reparations since the fall of apartheid.

79-337 Educational Policy and "School Choice": Historical and Contemporary Perspectives

Intermittent: 6 units

Fierce battles have been fought over education policy throughout American history. Parents, teachers, students, and everyday Americans have sought to position schools to meet often conflicting goals. This course introduces students to historical and contemporary perspectives on the rise of charter schools and school privatization, debates over religion in the classroom, legal questions surrounding segregation and forced bussing, as well as fundamental political shifts in who controls and funds public schools.

79-338 History of Education in America

Intermittent: 9 units

Americans have long understood schools both as mechanisms for inculcating communal values and as instruments for social reform. Schools have been alternatively described as pillars of democratic society and as authoritarian institutions for managing deviance. Institutions of education - whether schools, colleges, or universities - figure prominently in discussions of inequality and discrimination, opportunity and meritocracy. This course provides an introductory historical survey of American educational ideas and institutions. From debates in the 17th and 18th centuries over the proper balance of religious and secular education to fierce battles today over the role of the federal government, citizens have been politically mobilized through their concerns about education. By understanding the complicated history of American educational ideas and institutions, this course prepares students to engage critically with ongoing debates about the curriculum, vouchers, charter schools, and national standards.

79-339 Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961)

Intermittent: 6 units

How have American films portrayed juvenile delinquency and the juvenile justice system? What do filmmakers' portrayal of juvenile delinquency tell us about American culture and society? Do films vividly capture or badly distort the "realities" of crime and the operations of the justice system? This course uses feature films (to be viewed in advance of class) from the 1920s to the early 1960s, as well as sociological, psychological, and historical readings, to explore these issues. The course is run as a colloquium, with students playing central leadership roles in launching and guiding class discussions. The course will have a take-home midterm exam (essay), a final exam (essay), and a few short, written assignments linked to students' required oral presentations in class.

79-340 Juvenile Delinquency & Film: From "Boyz n the Hood"(1991) to "The Wire"(2002-08)

Intermittent: 6 units

How have American films portrayed juvenile crime, drug use, gang violence, and law enforcement responses (especially police and prisons) to juvenile crime and violence? How have American films portrayed individual juvenile delinquents, their families, and the communities in which they live? Do films vividly capture or distort the "realities" of juvenile crime and the operations of law enforcement? This course uses feature films from the late 20th and early 21st centuries, as well as social science and historical readings, to explore these issues. The course is run as a colloquium, with students playing central leadership roles in launching and guiding class discussions.

79-343 Education, Democracy, and Civil Rights

Intermittent: 9 units

What is the relationship between education and democracy? By examining a series of case studies at the intersection of education and the civil rights movement, this course will prepare students to approach contemporary educational debates as historically-informed critical thinkers. The controversy surrounding charter schools, vouchers, the common core, and the role of standardized testing cannot be understood outside the long history of debates regarding the relationship between education and democracy. Are schools meant to perpetuate the status quo? How did both traditional and more radical forms of education advance the struggle for civil rights? What role have students played in advancing civil rights and democracy? While exploring these questions, we will also partner with local high school students and teachers to bring our learning beyond the classroom.

79-345 Roots of Rock & Roll

Intermittent: 9 units

This course is about open source, collaborative innovation and the impact of social and technological change on American music. We will spend the first half on early "remix" music (slave songs, Anglo-Appalachian ballads, ragtime, and Depression era blues and country). After studying Bessie Smith, Woody Guthrie, Lead Belly, Hank Williams, and other early artists, we'll spend the second half on revolutionaries like Chuck Berry, Bob Dylan, Jimi Hendrix, and Janis Joplin. The format is informal lecture and discussion. Assignments include reading two books plus some articles, listening to short Spotify playlists, and writing three short essays.

79-346 American Political Humor

Intermittent: 9 units

This course takes a cultural approach to U.S. history since the Civil War, as seen by the nation's most astute and influential critics: its political humorists. Besides immortals like Mark Twain and contemporaries like Jon Stewart and Stephen Colbert, we will (re)discover the satirical yet hilarious voices of H.L. Mencken, Will Rogers, Lenny Bruce, Dick Gregory, Richard Pryor, Nora Ephron, Dave Chapelle, and others through essays, recordings and films. At its sharpest edges, humor addresses issues of class, gender and race in American life, and provokes alternative thinking about mass culture, consumerism, and conformity. Assignments include short analytical essays and a final paper.

79-350 Early Christianity

Intermittent: 9 units

This course examines the origins of Christianity in historical perspective. Using both Christian and non-Christian sources from the period, we will examine how and why Christianity assumed the form that it did by analyzing its background in the Jewish community of Palestine, its place in the classical world, and its relationship to other religious and philosophical traditions of the time. We will also examine historically how the earliest Christians understood the life and message of Jesus, the debates about belief and practice that arose among them, and the factors influencing the extraordinary spread of the movement in its earliest centuries. This course satisfies one of the elective requirements for the Religious Studies minor.

79-352 Christianity Divided: The Protestant and Catholic Reformations, 1450-1650

Intermittent: 9 units

At the dawn of the sixteenth century, most western Europeans shared a common religious identity as members of the Roman Catholic Church. Within less than two decades, this consensus began to crumble, and the very fabric of western culture was irrevocably altered. By 1550, Europe was splintered into various conflicting churches, confessions, sects, and factions, each with its own set of truths and its own plan for reforming the church and society at large. This period of rapid and unprecedented change in western history is commonly known as the Reformation. Though this term has traditionally referred to the birth of Protestantism, it also encompasses the simultaneous renewal and reform that occurred within Roman Catholicism. This course will survey the Reformations of the sixteenth century, both Protestant and Catholic, examining the causes of the Reformation, the dynamics of reform, and its significance for western society and culture. In the process, we will analyze such on-going problems as religious persecution and the accommodation of dissent, the relationship between religion and politics, and the interactions between ideology and political, social, and economic factors in the process of historical change.

79-353 Lock 'em up! Imprisoning Delinquent Youth, 1820s to the Present

Intermittent: 6 units

[Note: students who have already taken this course under its former number 79-353 and former title, Imprisoning Kids: Legal, Historical, and Moral Perspectives, may not enroll.] Can young lawbreakers be rehabilitated, or should they be removed from society to prevent them endangering others? Since the 1820s, reformers, philanthropists, and state officials in the Western world have wrestled with the question of how to reduce juvenile crime and turn delinquents into good citizens. The institutions and policies they created reflected their conceptions of young criminals, their backgrounds and families, their gender and their race. How did experts develop a body of knowledge about at-risk youth, what practices did they put into place, and what spaces did they build to house and contain the children? How have the children themselves responded, developing a sense of their own identity through compliance with or resistance to reformers' intent? In this course, we will explore ideas, practices, and institutions created to save juvenile delinquents, presented in reports and studies as well as fiction and film. Students will read and view a variety of primary and secondary sources from North America and Europe from the early nineteenth to the late twentieth centuries. Assessment will include participation in class discussion, short written assignments, and a final project.

79-355 Fake News: "Truth" in the History of American Journalism

Intermittent: 6 units

Scandal, conspiracy, and partisan propaganda have been among the stuff of media ever since newspapers first appeared in America, and now they figure prominently in electronic media as well. The question "What is truth" is not just a matter of philosophical speculation, but a critical issue in contemporary life, from elections to pandemics to climate change and war. Officials at the highest levels make dubious claims, and find media outlets to support them - all driven by motivations other than a commitment to truth. This course is literally "ripped from the headlines" examining conflicts over credibility in print and online in the context of historical experience. We'll explore ways of determining when news really is "fake" and when it's more likely to be "an inconvenient truth."

79-357 Science and the Body

Intermittent: 6 units

The human body has been always an object of fascination. Across time and space, people have wondered what lurks beneath the skin, why we get sick or remain well, and how to explain human variation. The methods used to investigate these questions have, however, varied widely. In this course, we will explore that diversity - from the dissection of medieval corpses to 19th century phrenology to contemporary biohacking - examining how different communities have sought to study, control, and change their bodies over the past several hundred years. In doing so, we will focus on how these scientific efforts were shaped by the political, cultural, and economic values of their times. We will also pay attention to the profound and often ongoing effects of these experiments, particularly on the people who served - both willingly and unwillingly - as their "human subjects."

79-359 Truth, Lies, and Propaganda: A Historical Inquiry

Intermittent: 9 units

For many commentators, the election of Donald Trump in November 2016 marks the beginning of the "post-truth" era, in which reality is no longer knowable, or even relevant. While this narrative certainly captures the unease that many Americans feel, it is historically inaccurate. There never was a time in the past when we could readily discern truth from falsehood without difficulty. The goal of this course is to examine the social history of truth. We will explore the concept of truth in philosophy and science; the evolution of methods for discovering facts about the world; the centrality of trust in knowledge production; and the innumerable ways that facts have been questioned, manipulated, discredited, purposefully ignored, and fabricated over the past several centuries. The course will include case studies from science, law, politics, war, art, journalism, and history.

79-360 Crime, Policing, and the Law: Historical and Contemporary Perspectives

Intermittent: 9 units

This seminar will critically explore the development of the American criminal legal system from the colonial era to the present. Students will learn how the present system took shape and what they can do to make it fairer and more effective in the future. Students will analyze the role of race, class, and gender in policy decisions that have created the American criminal legal system; how these factors play into the differential enforcement of laws in various communities; and how they affect outcomes in the legal system. Students will understand the history of social movements that have emerged to advocate for changes in our criminal legal system, including an analysis of when they have been successful and when they have not. Topics covered will include slave patrols, the 19th century origins of modern policing and incarceration, the factors leading to the emergence of urban police departments, changing understandings of crime and criminals, surveillance, the wars on crime and drugs (and their racial implications), mass incarceration, deaths in custody, police corruption, police oversight, and the portrayal of law in popular culture. The course is discussion-based and includes many opportunities to engage directly with people whose lives have been impacted by crime and the criminal legal system.

79-363 The Rise of Modern Golf, 1860 to the Present

Intermittent: 6 units

Aristocratic pastime or the people's game? This course will examine the emergence of golf as both a professional and amateur sport and as a popular leisure activity between 1860 and #8212; when Prestwick Golf Club in Scotland hosted the first (British) Open and #8212; and the present day. Students will read and discuss historical, sociological, and literary texts, and view several documentary and feature films as well. This course will have a take-home midterm exam (essay), a final exam (essay), and a few short, written assignments linked to students' required oral presentations in class.

79-366 Power & Politics: A Global History of Food

Intermittent: 9 units

The course will investigate the history of food from prehistory to the present day, and will consider examples from every corner of the world. We will begin with the science of food and taste, consider origins of agriculture and industry, and the implications of society and culture.

79-367 Disastrous Encounters

Intermittent: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. Disastrous Encounters explores the complex interaction between human beings and their environment by examining incidents in which those disasters have proven destructive or fatal to humankind. By the end of the class students will be able to: Explain the scientific principles behind "natural" disasters, including cyclonic weather, global climate change, volcanoes, earthquakes, tsunamis, river flooding, famines, and diseases. Analyze to what extent a given disaster is in fact "natural" at all, but rather was either caused by or exacerbated by human actions. Draw connections between different types of disasters, recognizing that major disasters often produce predictable secondary disaster effects. Read documents critically, especially in terms of the author's agenda and the author's likely biases. Write strong analytical essays.

79-368 Un-natural Disasters: Societies and Environmental Hazards in Global Perspective

Intermittent: 6 units

In the wake of Hurricane Katrina, Neil Smith famously observed that "there is no such thing as a natural disaster." This course takes a cue from Smith by examining the social production of disasters in the past and present, from acute environmental events like typhoons and earthquakes to disasters of "slow violence" like chronic exposure to toxic pollution and food insecurity. Examining case studies from around the world, we will explore how these different forms of disaster collide with inequalities of race, class, and gender - and in the process challenge us to rethink the relationship between nature and society.

79-370 Technology in the United States

Intermittent: 9 units

This course examines the ways in which technology and society have shaped each other in the United States from the colonial era to the present. Topics include Native Americans and technologies, farming, industrialization, transportation, automobiles, aerospace, information technology, drugs, and biotechnology. Students will read a textbook, write brief essays about technologies of their choice, and discuss their essays and the text in class. The course welcomes students from any major.

79-371 African American Urban History

Intermittent: 9 units

As the ravages of the Covid-19 pandemic gradually lifts, the plight of poor and working class people of African descent will continue to occupy a prominent place in discussions of today's urban community. Effective contemporary public policies, movement strategies, educational programs, media campaigns, and sensitive philanthropic decisions will require deeper and more thoughtful perspectives on the history of urban race and class relations in the past. Focusing on the development of African American urban history from its colonial beginnings through today's "Black Lives Matter Movement," this course will emphasize the many ways that African Americans shaped American urban life through their roles as workers, community-builders, and social justice activists. In addition to weekly classroom discussions of assigned readings, students will write a series of short essays (based upon a mix of secondary and primary sources) on selected topics/themes in the development of African American urban life, culture, and politics.

79-372 The Rise and Fall of Pittsburgh Steel

Intermittent: 6 units

For over 150 years, the Pittsburgh region was world-renowned for the scale and intensity of its iron and steel manufacturing complex. This mini course will trace the origins, explosive growth, stagnation and ultimate collapse of this remarkable industrial complex. Students will gain an understanding of Pittsburgh's rich industrial history - what makes it "The Steel City," understand the emergence and evolution of iron and steel making technology, appreciate the impact of Pittsburgh's iron and steel industrialization on living and working conditions for workers, and analyze the factors that drove the emergence of Pittsburgh steel then to its decline and collapse. The course is structured loosely around a set of periods in Pittsburgh's history through which key themes are drawn.

79-373 Culture and Revolution: The Socialist Experiment in Soviet Russia

Intermittent: 6 units

In 1917, revolutionaries took power in Russia to create the world's first socialist society. In a series of radical and unprecedented experiments, they attempted to remake every phase of social and cultural life, from sexual relations to art to education. How could life be lived in a new way and better way? What values should replace the old traditions based on patriarchy and class hierarchy? How could ordinary people be empowered to create a new culture? In this course, we will study the 1920s, a riotous decade of experimentation in cultural, social, and political life.

79-375 Science & Religion

Intermittent: 6 units

A widely held notion is that science and religion are perennially at "war" with one another. Debates over evolution, and more recently climate change, are cited as examples, while predictions that science will eventually make religion obsolete are at least as old as the Enlightenment. Nevertheless, both science and religion continue to thrive in the 21st century, which raises the question of whether these two ways of seeing the world might, for some people at least, be more complementary than conflictual. We'll explore the history of the relationship between science and religion and the different "ways of knowing" employed by each. Some common assumptions will be critically examined as we consider questions of fact and value, and the competency of science and religion to address the major challenges of our day.

79-377 Food, Culture, and Power: A History of Eating

Intermittent: 9 units

How can human societies ensure that 8 billion people have enough good food to eat without exploiting people or the planet? This course will start with the assumption that the answer to that question requires not only technological innovations, but also an understanding of the cultural and political dimensions of food. For the first half of the course, we will explore the history of human eating, starting in deep time and then moving toward the present, considering along the way the historical evolution of food production and consumption, paying attention to both cultural diversity and cultural exchanges of foods and cuisine. Students will pursue individual research projects focused on a topic of their choice related to major course themes during the second half of the semester. Evaluation based on in-class participation, analytical reflections on weekly readings, and the research paper.

79-378 Gender in South Asia

Intermittent: 9 units

This course introduces students to women's position and gender relations in South Asia from a historical perspective. Using gender as a lens of examining the past, we will examine how politics of race, class, caste and religion affected and continue to impact women in South Asian countries, primarily in India, Pakistan, Bangladesh and Sri Lanka. Attention is drawn to the processes by which gender is socially constructed, the prevalent forms of gender disparity and discrimination, as well as the factors of change to which these are subject. These themes are situated in the broader context of the region's history, society, and culture. We will reflect upon current debates within South Asian women's history in order to examine some of the issues and problems that arise in re-writing the past from a gendered perspective. The chronological focus of this course is on the condition of women in the subcontinent from the ancient times till the present day. Students are encouraged to make comparisons between women's position and gender relations in South Asia with the corresponding situations in their societies. Analysis and appreciation of the cross-cultural aspects of women's position and gender disparity constitute integral elements of the envisaged learning outcomes of this course. It would be of general interest to all students concerned about women's position and gender issues, as well as those interested in South Asia. To help us evaluate the different historical and temporal experiences of South Asian women, this course will extensively use primary documents, secondary readings, films, and contemporary newspaper and Internet articles. Students will be required to actively engage and participate in class discussions and group debates, which will form a substantial part of individual evaluations.

79-379 Extreme Ethnography

Intermittent: 9 units

Observation, participation and direct experience of "the field" are hallmarks of anthropological ways of knowing, and their representation has played a foundational role in ethnographic writing both past and present. Yet reflexive and postmodernist explorations of these topics have triggered contentious debates over the nature of anthropology as a scientific or humanistic enterprise, and over its ethical, political and epistemological value. In this seminar, we will approach such questions through an exploration of the extremes of ethnographic fieldwork and writing. We will consider such topics as: the colonial history and politics of explorers and ethnographers; liminality and the place of extreme experience and #8212; such as cultural dislocation, violence, derangement, intoxication, sex, possession, and dreaming-in fieldwork and writing; field-notes as an ethnographic genre, and their relationship to "official" published ethnography; ethnographic surrealism and surrealist ethnography; the dimensions of sensory experience (visual, auditory, olfactory, etc.) in fieldwork and ethnography; collecting and the powers of "exotic" objects; inter-subjectivity and its implications; and experimentation with alternate ethnographic forms, such as autobiography, film, diary, and poetry.

79-380 Hostile Environments: The Politics of Pollution in Global Perspective

Intermittent: 9 units

Earth is an increasingly toxic planet. Fossil-fueled industrialization, chemical engineering, and resource-intensive consumerism have generated immense wealth, but they have also left long-term, cumulative legacies of toxic pollution and ecological harm. While these legacies affect everyone, their impacts are by no means evenly distributed. In this course, we will use the tools of anthropology, political ecology, and history to examine experiences of toxic exposure in different parts of the world, including Pittsburgh. Our analyses will ask how inequalities of race, class, gender, and ability shape exposure as well as how cultural differences create divergent understandings of ecology, health, and their interrelationship. We will consider, moreover, how these disparities shape what people know about pollution and whether/how they demand accountability for it. Cases we explore will range from acute industrial disasters (and their aftermath) to the harms experienced by other-than-human beings to the gradual, often invisible exposures that affect all of us to varying degrees.

79-383 The History of Capitalism

Intermittent: 9 units

What is capitalism? How does it differ from systems that preceded it, and how did it come to revolutionize the globe? This course will cover the global development of capitalism from the 16th century to the present. We will examine the theories of Karl Marx and Adam Smith, who both attempted to theorize the new system of labor organization. We will look at how the transition from feudalism to capitalism took place, including the role of new world slavery, commodity production, dispossession of the peasantry, and changes in the household and gender relations. We will examine "globalization," the latest dynamic phase of capitalism and its impact on people. Finally, we will discuss the advent of robotization, the loss of industrial jobs, and the potential impact of casual labor, low wages, and unemployment on democracy and the rise of a technocratic elite.

79-385 Out of Africa: The Making of the African Diaspora

Intermittent: 9 units

The trans-Atlantic slave trade dispersed Africans in the New World and the Old, creating the African Diaspora. Generations of scholars have disputed whether descendants of enslaved Africans could have retained any of their African culture and/or fully assimilated into New World societies. This course will combine a chronological, geographical, and a thematic approach to the creation of new Africa-inspired cultures in both Africa and the African Diaspora. It will explore societies in the Caribbean, the US South, Latin America, and Africa and address themes, such as Africanisms, African survivals, African retentions, Creole languages, and religion.

79-387 General Francisco Franco: Fascism and its Legacies in Spain

Intermittent: 6 units

Francisco Franco was Europe's longest-ruling dictator. He ruled over Spain from 1939 to 1975. This course will examine the social and cultural context of the rise of Fascism in Spain. We will focus especially on the colonial legacy of Spanish fascism, the violent overthrow of the democratic II Spanish Republic and Franco's seizure of power during the bloody Spanish Civil War. We will have the opportunity to learn about the international volunteers, including from the United States, who joined the fight against fascism and how the Spanish Civil War was decisive in shaping WWII. We will also discuss the decades of Franco's lengthy dictatorship, the social and cultural politics in transitioning Spain to democracy after his death and the legacy of Spanish Fascism in contemporary Spain. In addition to class lectures, students will become familiar with these themes through the reading and analysis of historical texts and memoirs, participation in a workshop with the director of the Abraham Lincoln Brigades Archives, the viewing of documentary film, and by engaging with the current volatile debates in Spain about the historical memory of fascism.

79-388 Sports in American Culture

Intermittent: 9 units

[Note: students who have taken course number 79-388, with former titles, Race, Gender, and the Politics of Sports in America since 1900 or 79-388, History of Sports in the United States, may not enroll.] In this course, we will survey the history of sport in the United States from the late nineteenth-century into the twenty-first century. While we will discuss star athletes, famous games, and popular teams, we will focus more so on evaluating the significance of sport in American history. Specifically, we will analyze sports through four themes: westernization/globalization; the emergence and development of Capitalism; industrialization and technological change; and democratization. By doing so, we will examine the changing power relationship between the athletes, owners, and consumers (fans). We will pay particular attention to athletes' changing role in American society and the public's growing expectation that these men and women speak or act on social and political issues. By semester's end, students will look beyond box scores and critically assess how sports has reflected larger trends in our society as well as its continued influence on American life.

79-391 Nations and Nationalisms in South Asia

Intermittent: 9 units

This course examines the role which nationalism has played in the formation and political development of the nations and states of South Asia. It, therefore, examines nationalist forces in anti-colonial struggles, in post-colonial state formation and in contemporary political developments. It will be of relevance to students with an interest in political developments in Asia, with particular reference to forms of nationalism and nation-building.

79-392 Europe and the Islamic World

Intermittent: 9 units

Europe and the Islamic World explores the complex relationship between (Christian) Europe and Islamic civilization, from the conquest of the Byzantine Levant to modern-day Islamic immigration into Europe. The course will focus on a few landmark events in European/Islamic relations, such as the crusades, as well as various intellectual models describing European/Islamic relations over time. The course will also focus on developing research, writing, and documentary analysis skills relevant to the study of history.

79-393 Institutions of the Roman Church

Intermittent: 9 units

This course is only offered at Carnegie Mellon's campus in Qatar. This course will explore the history of the Catholic Church, with a particular focus on the church as an evolving European institution. Although we will have to deal with theological arguments at times, abstract theology will not be the focus of the course. Instead, the course will be centered on two main questions. First, how did the Catholic Church manage to persist, for nearly two millennia, as a stable institutional entity within an ever-changing European milieu? Secondly, to what degree did the Catholic Church influence and/or reflect developments within Western European culture?

79-394 Exploring History through Geography

Intermittent: 6 units

For studying the past, space can be as important as time. Digital mapping and GeoLocation technologies influence our everyday interactions and perceptions of the world around us. Historians are thinking about how these technologies can change their fields of study, too. Through the "spatial turn" in the Humanities and Social Sciences, historians are using spatial experience to think more deeply about the meaning of place and space. Visualizing spatial relationships via new technologies can offer meaningful new ways to approach historical questions. This course will consider viewpoints from the discipline of Geography and explore the impact of new methods in the Digital Humanities, including the impact of digital tools such as Geographic Information Systems (GIS).

79-395 The Arts in Pittsburgh

Intermittent: 9 units

This course will examine the arts in Pittsburgh, both historically and in the present. We will pay special attention to musical events and art exhibits scheduled by the city's concert halls and art museums, several of which we will attend as a group. Our "curriculum," in other words, will derive partly from the city's artistic presentations themselves, which will provide a springboard for reading assignments, discussions, a small research project (which I will work out individually with each of you), and one or two essay exams. The History Department will pay for students' admission to all museums. However, students will be charged a supplemental fee (at discounted prices) to help subsidize the considerable expense of purchasing tickets for performances by the Pittsburgh Symphony, Pittsburgh Opera, Pittsburgh Ballet, Chamber Music Pittsburgh, or other musical organizations. Attendance at all musical events and art exhibits is required.

79-396 Music, Art, and Society in 19th and 20th Century Europe and the U.S.

Intermittent: 9 units

This course will explore the interrelations between society, classical and popular music, and art in the nineteenth and early twentieth centuries in Europe and the United States. We will examine the importance of different musical forms in the life of society and how music and art reflected changing political and cultural consciousness in several national settings. We will also analyze trends in artistic expression by examining the collections and historical development of several notable European and American art museums. The "curriculum" in other words, will derive from the artistic presentations themselves and #8212; symphonies, operas, chamber music, ballet, and art exhibits and #8212; which will provide a springboard for reading assignments, discussions, a personal artistic journal, and written assignments that will help you synthesize your diverse forays into the history of music and art. In addition to visiting Carnegie Museums of Pittsburgh, students will be taking to the performances of the CMU School of Drama, Pittsburgh Symphony, Pittsburgh Opera, chamber music concerts, performances of the Pittsburgh Cultural Trust. A supplemental fee of \$170 will be charged to help subsidize the considerable expense of purchasing tickets for concerts and performances.

79-400 Global Studies Research Seminar

Fall: 12 units

This research seminar is the capstone course for Global Studies majors. The course is designed to give you a chance to define and carry out a research project of personal interest. The first few weeks of the course will be devoted to developing a research topic and locating sources. We will then work on how to interpret and synthesize sources into a coherent and compelling thesis before you begin drafting your paper. Your research may be based on in-depth reading of a body of scholarly work, field notes from ethnographic observations, archival research, analysis of literary or visual media, or some combination of these sources. Incorporation of some non-English language sources is strongly encouraged where possible. Independent work, self-initiative, participation in discussion, and peer evaluations are required. There are several interim deadlines that will be strictly enforced in order to ensure successful completion of the course.

79-420 Historical Research Seminar

Fall: 12 units

The purpose of this research seminar is to help students conceptualize, design, organize, and execute a substantial research project that embodies and extends the knowledge and skill set they have been developing as History majors at Carnegie Mellon. The identification, collection and interpretation of relevant primary source data are integral parts of this intellectual task. Students will hone written and oral presentation skills, deepen their command of research methodologies and strategies, and sharpen their abilities as a constructive critic of others' research. The seminar seeks to develop these intellectual skills through a combination of in-class, student-led discussions of everyone's research-in-progress, and regular individual consultations with the instructor.

Prerequisite: 79-200 Min. grade C

79-449 EHPP Capstone Course

Fall: 12 units

In this Fall 2023 capstone course, Ethics, History, and Public Policy majors will carry out a collaborative or individual research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. Students will develop an original research report based on both archival and contemporary data and present their results in a public forum at the end of the semester.

Please note: this semester we are experimenting with a more flexible set of research options for EHPP students, rather than a single project topic that all students are required to work on. Collaborative projects in groups of 2-3 students are encouraged, but individual projects that integrate historical, ethical, and policy perspectives are permissible too.

79-452 Women's Bodies and Cultural Politics

Intermittent: 3 units

This course explores the fraught, often shameful, often triumphant, and sometimes deadly cultural ideas and expectations around cis-gendered women's bodies. We want to explore what the stories we attach to female bodies mean, who they serve, and whether they are changeable. Are our ideas derived from science or culture? And why might it matter? Built from a popular U.S. based-course on the Pittsburgh campus, this course aims to bring feminist analysis around American cis-gendered women's bodies to an audience in Doha, and asks you to build, through class discussion and assignments, your own analyses of how these ideas and concepts work in your own culture. You will no doubt come to different conclusions, which is the goal: for you to think independently and analytically, to build your own ideas. The course is organized topically. We will learn some reproductive anatomy and biology (including the menstrual cycle), and also survey reproductive politics, sexuality, gender-based violence, and a topic of your choice. It will be heavily discussion based. No prerequisites or prior experience with this material needed and #8212;open to all.

79-453 Global Water and Development

Intermittent: 3 units

Water is necessary for all forms of life on Earth. An estimated 1 billion humans do not have satisfactory drinking water; an estimated 2 billion do not have access to adequate sanitation facilities for human health, safety, and dignity. For more than a hundred years, to address social inequalities in access to water, international organizations and scholars have created their own theories and ideas about providing water. This international community points out the social and cultural implications of technical provision of water resources. These debates about "development" showcase diverse theories, recommendations, and contradictions. The purpose of this course is to introduce students to critical studies of water and development. We will consider complex stories of social change, including unintended consequences; human and environmental impacts; and debates among experts.

79-454 The TransOceanic Railway

Intermittent: 3 units

This course is an introduction to railway restructuring and privatization, which arguably began in exactly 1990 with the privatization of Argentina's railways. The Argentine model has been replicated on other continents and in many settings and is modeled on the successful USA model of private ownership and operation of freight rail, which is generally considered a model for the world. Conversely, passenger rail in the USA almost disappeared while in the UK it has enjoyed a spectacular run with a doubling of ridership since the privatization of its railways in roughly the same era, i.e., the Thatcher years. The UK's model has been replicated in various forms throughout Europe and beyond.

79-465 The Arts in Qatar

Intermittent: 9 units

This course will examine the arts in Qatar, both historically and in the present. We will focus especially on art exhibits and musical events scheduled by the city's museums and concert halls during the Spring 2020 semester. The "curriculum" will derive from the artistic presentations themselves, which will provide a springboard for reading assignments and research papers in the history of music and art. We will also examine the historical development of cultural institutions in Qatar.

79-470 Simulating Conflict Resolution

Intermittent: 3 units

This course is only offered at Carnegie Mellon's campus in Qatar. This pass-fail, 3-credit course for the Qatar campus is designed to prepare students for a capstone event: an international conflict resolution exercise, to be held in the 2018 Spring semester, that simulates a current Middle Eastern crisis. The course will consist of two parts. First, students will meet weekly with an instructor for 1 hour/week to discuss the historical and modern Middle East, so that they will be prepared to participate meaningfully in the simulation. For these classes, students will be expected to complete and discuss readings prepared by the instructor. Secondly, students will participate in the simulation exercise in late spring, taking the role of one of the Middle Eastern actors (these will be decided ahead of time) and role-playing their nation's response to the specific crisis scenario. Finally, after the simulation, students will submit to the instructor a reflection paper on what they learned from participating in the event. Suggested pre- or co-req: Conflict Resolution (80-242 or 70-321).

79-491 Independent Study

Intermittent

An Independent Study is meant for students with a special interest in an area not covered by a formal history course. Readings and other work are negotiated between the student and an individual faculty member.

79-505 Internship: Social & Political History

All Semesters

The Social and amp; Political History program strongly encourages students to locate internship opportunities in Pittsburgh or elsewhere that complement their historical interests (as, for example, in a museum or historical society) or in areas of policy research that complement their historical interests (as, for example, in a government agency or non-profit organization). To earn academic credit for their internship, students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to their academic interests; and share their experience with other Social and amp; Political History majors. The Academic Advisor will assist students with matching their interests to local organizations. SPH students can earn up to 9 units in each internship. Please note, however, that internship credits (students may complete up to three internships) do not count toward fulfillment of course requirements for the SPH major (though the units do count toward graduation).

79-506 Global Studies Internship

Fall and Spring

This course provides Global Studies majors with a chance to explore global connections in Pittsburgh. Majors, working in close consultation with the Global Studies director and advisor, will arrange an internship with a non-governmental organization (usually in Pittsburgh) whose mission has a global reach. This could include an organization that supports projects in other countries, works with immigrants in the Pittsburgh area, or participates in international policy making/governance. We strongly encourage students to seek out opportunities that require use of a second language. Students will be required to maintain a weekly journal; write a short critical reflection on how the internship connects to academic work; and share their experience with other Global Studies majors. Global Studies advisor and director will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work. Prerequisite: Students must be Global Studies majors and obtain permission for the proposed internship from the Global Studies advisor.

79-510 Global Studies Guided Reading

All Semesters: 3 units

Global Studies Guided Reading (Fall 2023: The Environment and Climate Change) The main goal of this seminar is to encourage students to engage deeply with four books on a distinct topic, and discuss them under the guidance of the professor. You could think of this seminar as a more academically-oriented monthly book club! The small size of the seminar allows for a deep immersion in the readings, and for the development of critical thinking among students. The four books are selected by the professor, and the selection is based on several criteria, including the books' impact, current relevance, regional foci, as well as diversity and inclusivity reflected by the authors' different social, racial, and geographical backgrounds. The topics of the seminars each semester will vary, but all will have global relevance. (For instance, the Fall '22 seminar will focus on the environment and climate change, and the Spring '23 seminar will deal with the topic of cultural and historical memory). Important: In order to encourage all of the students' constant participation and their deep engagement with the books, as well as foster a sense of intellectual community, this seminar will be strategically small. For these reasons, only the GS majors will be allowed to register for this monthly guided reading. Meets monthly on Fridays.

The Major in Information Systems

Joe Mertz, Faculty Director

Gary DiLisio, Director of Undergraduate Education

Correy Dandoy, Senior Academic Advisor and Communications Manager

Jessica Lutz, Academic Advisor

Sarah Avery, Academic Advisor

Susan Miller, Senior Business Administrator

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Location: Hamburg Hall 3031

www.cmu.edu/information-systems/ (<http://www.cmu.edu/information-systems/>)

Did you enjoy computer science or more technical courses in high school, but are mostly interested in the practical and social applications of technology? Do you have a passion for business and want to use advanced technology to change how companies work? Do you want to learn how data and technology can be harnessed for social good?

Carnegie Mellon University's **Information Systems (IS) program**, a joint degree program between the Heinz College and Dietrich College of Humanities and Social Sciences is strongly technical, drawing from Carnegie Mellon's leadership in computer science, human-centered design, business management and software engineering. It is deeply rooted in the humanities and social sciences, allowing students the lifelong benefits of a rich liberal arts education. And it provides pathways for students to find their own Information Systems niche through advanced study and research with leading researchers. As a result, our graduates are uniquely positioned to envision and drive the positive organizational change that technology makes possible.

Artificial intelligence. Machine learning. Deep learning. Big data. Social networks. Neural networks. Robotics. Automated voice assistants. Blockchain. Driverless vehicles.

Do you want to use technologies like these to benefit companies, governments, and society? CMU offers the world's best undergraduate IS program and will help you do just that. In fact, many of the world-changing technologies listed above were invented here on campus—there is no better place to become a tech leader than CMU.

The field of Information Systems involves the effective design, delivery, and use of information and communications technologies to solve problems for companies, governments, and society. Equally, it is about understanding and measuring the impacts of these technologies on people and communities so they can be deployed ethically.

As an IS student, you will build a solid foundation in computing, communications, and software development. You will also study social sciences and organizational theory to develop "big picture" critical thinking and understand the human impacts of technological change. This blend prepares you to take a leading role in our digital future. The flexible nature of the program encourages students to explore their own interests through program electives, study in a contemporary concentration or through optional second majors and minors.

IS students are well prepared to pursue graduate work in a wide range of fields. For students interested in master's degree-level graduate work at Carnegie Mellon, there are many possibilities, including accelerated Masters degree programs in Information Systems Management, Human Computer Interaction, Information Security Policy and Management, Engineering Technology and Innovation Management, and Business Administration.

IS graduates continue to be in high demand in the information-age workplace. There has been a strong job market for IS students in recent years, and national trends indicate that this is likely to continue. IS majors often take jobs in consulting companies, major software firms, large corporations, and start-up companies. Internship opportunities closely parallel the job market.

In addition to General Education Requirements and basic prerequisites in Mathematics and Computer Science, The IS program curriculum includes:

- A broad grounding in humanities and social sciences to promote self-directed learning, critical thinking, and interdisciplinary problem-solving.

- An Information Systems Core to provide the technology, project management, and business-facing skills needed to design and build effective real-world systems solutions.
- An Information Systems Breadth focused on professional communications, quantitative analysis, and how technology functions in society.
- A Concentration that gives you the flexibility and agency to gain expertise in a supporting area and define your own niche in IS.

The IS major is the perfect place for you if you are passionate about using technology for positive gains across society, both economic and humanistic.

IS Commitment on Diversity & Inclusion:

Diversity, equity and inclusion are core values of the Information Systems Program. We strive to foster a community that promotes inclusiveness and a positive sense of belonging among all students within the program. Together, we value and celebrate the unique identities of our students and aim to create a culture where they feel empowered to share their experiences and ideas, and engage in meaningful academic, leadership, and social opportunities. We aim to elevate cultural awareness through education, programming, and an environment that embraces differences.

Study Abroad Options in Information Systems:

Given the importance of globalization, we encourage students to consider expanding their international experience by spending a semester studying abroad. The IS program is very flexible in allowing students to pursue these opportunities. With careful planning, study abroad is possible during most semesters. Students interested in study abroad should talk with the IS Academic Advisor to help plan an appropriate course of study. With prior approval, study abroad courses may be applied to major requirements.

Information Systems as Additional Major or Minor:

Information Systems is not available as either an additional major or minor.

Curriculum

The Information Systems major is offered only as a Bachelor of Science (B.S.) degree. In addition to major requirements outlined below, all Information Systems students must fulfill the General Education requirements for the Dietrich College of Humanities and Social Sciences. A total of 360 units is required for the degree.

Requirements are subject to revision. Advisor approval is required for each student's major curriculum plan. Any proposed course substitutions to courses required for the IS major must be approved in advance by the IS Academic Advisor.

Technical Core (Prerequisites)

Information Systems requires completion of prerequisite courses in Mathematics and Computer Science. All prerequisites must be successfully completed prior to the start of Fall semester, junior year.

Mathematics

Complete one of the following math courses:

| | | Units |
|--------|--|-------|
| 21-112 | Calculus II (pre-requisite of 21-111) | 10 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-240 | Matrix Algebra with Applications | 10 |
| 80-210 | Logic and Proofs | 9 |

Computer Science

Three Computer Science courses are required. To maintain normal progress toward the Information Systems degree, students must complete 15-121 Introduction to Data Structures prior to the start of Spring Semester, sophomore year.

Students entering the program as freshmen will have the option to complete a Computer Science Placement Test. Depending on appropriate Advanced Placement credit and/or results of the Computer Science Placement Test, entering students may place directly into 15-112

(<http://coursecatalog.web.cmu.edu/search/?P=15-112>) or 15-121 (<http://coursecatalog.web.cmu.edu/search/?P=15-121>). 15-110 (<http://coursecatalog.web.cmu.edu/search/?P=15-110>) is taken as the first Computer Science prerequisite unless a student places directly into 15-112 (<http://coursecatalog.web.cmu.edu/search/?P=15-112>) or 15-121 (<http://coursecatalog.web.cmu.edu/search/?P=15-121>). Students that do not gain a placement into 15-112 (<http://coursecatalog.web.cmu.edu/search/?P=15-112>) or 15-121 (<http://coursecatalog.web.cmu.edu/search/?P=15-121>) must begin the sequence with 15-110 (<http://coursecatalog.web.cmu.edu/search/?P=15-110>) and must complete it with a grade of D or above prior to entering 15-112 (<http://coursecatalog.web.cmu.edu/search/?P=15-112>).

| | | Units |
|--------|--|-------|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-121 | Introduction to Data Structures | 10 |

Note: Students cannot receive credit for both 15-104 Introduction to Computing for Creative Practice and 15-110 Principles of Computing. Students may also take 15-122 (<http://coursecatalog.web.cmu.edu/search/?P=15-122>) Principles of Imperative Computation in place of 15-121 (<http://coursecatalog.web.cmu.edu/search/?P=15-121>) Introduction to Data Structures but should first consult with their academic advisor prior to doing so.

Information Systems Core

In the Information Systems Core, students will learn the basic skills necessary to analyze, design, implement, and test high-quality, cost effective information systems. The Information Systems Core consists of seven courses (not including 67-100 and 67-200).

Complete all of these courses:

| | | Units |
|--------|---|-------|
| 67-100 | Information Systems First Year Colloquium | 1 |
| 67-200 | Information Systems Research Colloquium | 1 |
| 67-250 | The Information Systems Milieux (Spring Semester Only) | 9 |
| 67-262 | Database Design and Development (Fall Semester Only) | 9 |
| 67-272 | Application Design and Development (Spring Semester Only) | 12 |
| 67-373 | Information Systems Consulting Project (Spring Semester Only) | 12 |
| 17-313 | Foundations of Software Engineering | 12 |
| 95-422 | Managing Digital Transformation | 9 |

Complete one of these three courses:

| | | Units |
|--------|---------------------------------------|-------|
| 05-391 | Designing Human Centered Software | 12 |
| 05-410 | User-Centered Research and Evaluation | 12 |
| 05-452 | Service Design | 12 |

Information Systems Breadth

In the Information Systems Breadth, students will study key areas fundamental to understanding and solving problems in information systems. At least one course is required from each of the following categories:

Professional Communications

Information systems professionals communicate with a wide range of people in most organizations and often facilitate communications between diverse groups of stakeholders. Consequently, the most successful professionals typically are those with strong communication skills. These courses help students see that the structure and presentation of information affects how well (and how easily) it can be understood and used.

Complete one of the following courses:

| | | Units |
|-----------|--|-------|
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 51-261 | Design Center: Communication & Digital Design Fundamentals | 9 |
| or 51-262 | Design Center: CD Fundamentals: Design for Interactions for Communications | |
| 67-265 | Design Fundamentals: Shaping Interactions and Experiences | 9 |
| 67-338 | Information & Grid Design | 9 |

| | | |
|-----------|---|---|
| 70-321 | Negotiation and Conflict Resolution | 9 |
| 70-340 | Business Communications | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 70-350 | Acting for Business | 9 |
| 76-270 | Writing for the Professions | 9 |
| 84-250 | Writing for Political Science and Policy | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-341 | Team Dynamics and Leadership | 9 |
| or 70-341 | Team Dynamics and Leadership | |

Quantitative Analysis and Research Methods

This area focuses on decision making and data analysis — essential to development of useful information systems. This area exposes students to analytic methods in the social sciences and quantitative methods for approaching complex methods.

Complete one of the following courses:

| | | Units |
|--------|--|-------|
| 21-257 | Models and Methods for Optimization | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 36-225 | Introduction to Probability Theory | 9 |
| 36-235 | Probability and Statistical Inference I | 9 |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-350 | Statistical Computing | 9 |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 67-285 | Across the Universe from Intelligent Agents to Users | 9 |
| 67-364 | Practical Data Science | 9 |
| 73-265 | Economics and Data Science | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-251 | Empirical Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |

Innovation and Entrepreneurship

The focus of this area is to apply disciplined techniques to generate ideas that have value in a market, and bring them through design, feasibility testing, and frequent revision, towards a potential launch. Students must complete 67-272 Application Design & Development in order to fulfill one of the courses below towards their Innovation and Entrepreneurship requirement.

Complete one of the following courses:

| | | Units |
|--------|---|-------|
| 05-470 | Digital Service Innovation | 12 |
| 17-356 | Software Engineering for Startups | 12 |
| 67-443 | Mobile Application Design and Development | 12 |
| 94-491 | Lean Innovation Lab | 12 |

Information systems concentration

The study of Information Systems can take many paths; **Concentrations** allow students to find the path that best suits their plans and aspirations. They also allow students to establish relationships with leading researchers in their area of interest.

IS Concentrations include:

- Data Analytics
- Health Information Systems
- Technology & Arts Enterprises
- Technology & International Development
- User Experience (UX) Design

Alternatively, students may choose from an approved list of minors or additional majors, including those offered through the Integrative Design, Arts, and Technology (IDEATe) (<https://ideate.cmu.edu/undergraduate->

programs/) initiative that blend information systems and the arts as only Carnegie Mellon University can.

IDEATe minors:

- Game Design (<https://ideate.cmu.edu/undergraduate-programs/game-design/>)
- Animation & Special Effects (<https://ideate.cmu.edu/undergraduate-programs/animation-special-effects/>)
- Design for Learning (<https://ideate.cmu.edu/undergraduate-programs/learning-media/>)
- Media Design (<https://ideate.cmu.edu/undergraduate-programs/media-design/>)
- Soft Technologies
- Sonic Arts (<https://ideate.cmu.edu/undergraduate-programs/sound-design/>)
- Innovation & Entrepreneurship (<https://ideate.cmu.edu/undergraduate-programs/innovation-and-entrepreneurship/>)
- Intelligent Environments (<https://ideate.cmu.edu/undergraduate-programs/intelligent-environments/>)
- Physical Computing (<https://ideate.cmu.edu/undergraduate-programs/physical-computing/>)
- Immersive Technologies in Arts & Culture (<https://ideate.cmu.edu/undergraduate-programs/immersive-technologies-in-arts-culture/>)

Other approved minors and additional majors include:

- Artificial Intelligence (<https://www.cs.cmu.edu/bs-in-artificial-intelligence/minor/>)
- Business Analytics and Optimization (<http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#minorinbusinessanalyticsoptimizationtextcontainer>)
- Computational Biology (<https://cbd.cmu.edu/education/undergraduate/minor-in-computational-biology.html>)
- Computational Finance (p. 880)
- Computer Science (p.)
- Cybersecurity & International Conflict (p. 421)
- Decision Analytics & Systems (<https://www.heinz.cmu.edu/programs/decision-analytics-and-systems/>)
- Decision Science (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionciences/#minorstextcontainer>)
- Economics (p.)
- Economics & Statistics (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofstatistics/#econstattextcontainer>)
- Engineering Studies (p. 173)
- Human-Computer Interaction (p.)
- Humanities Analytics (<https://www.cmu.edu/dietrich/english/academic-programs/humanities-analytics/ha-minor.html>)
- Information Security, Privacy and Policy (<https://www.isri.cmu.edu/education/undergrad/ispp-minor/>)
- Language Technologies (p. 717)
- Machine Learning (p. 718)
- Neural Computation (p. 719)
- Operations & Supply Chain Management (p.)
- Policy & Management (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionciences/#minorinpolicyandmanagementtextcontainer>)
- Robotics (p.)
- Science, Technology & Society (p. 568)
- Software Engineering (p. 720)
- Statistics (p. 546)
- Technology & Policy (p. 173)

The following areas are available as a second major only:

- Behavioral Economics, Policy, and Organizations (BEPO) (p.)
- Business Administration (<http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/#additionalmajortextcontainer>)
- Cognitive Science (<https://www.cmu.edu/dietrich/psychology/undergraduate/prospective-students/academics/cognitive-science/>)
- Economics & Statistics (<http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduateeconomicsprogram/#dualdegreeadditionalmajortext>)

- Engineering & Public Policy (p. 130)
- Statistics & Machine Learning (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofstatistics/#statsmltextcontainer>)

Sample Curriculum

| First-Year | | Second-Year | |
|---|---|---|---|
| Fall | Spring | Fall | Spring |
| 67-100 Information Systems First Year Colloquium | 67-250 The Information Systems Milieux | 67-262 Database Design and Development | 67-272 Application Design and Development |
| 15-110 Principles of Computing | 15-112 Fundamentals of Programming and Computer Science | 15-121 Introduction to Data Structures | Quantitative Analysis Requirement |
| 36-200 Reasoning with Data | Grand Challenge Seminar | Professional Communications Requirement | General Education Course |
| 76-101 Interpretation and Argument or other approved first-year writing options | General Education Course | General Education Course | General Education Course |
| Math Requirement | General Education Course | Elective Course | Elective Course |
| Elective Course | | | |
| 99-101 Computing @ Carnegie Mellon | | | |

| Third-Year | | Fourth-Year | |
|--|---|---|--------------------------|
| Fall | Spring | Fall | Spring |
| 17-313 Foundations of Software Engineering | 67-373 Information Systems Consulting Project | 95-422 Managing Digital Transformation | Concentration Course |
| Concentration Course | Concentration Course | Concentration Course | General Education Course |
| HCI Requirement | General Education Course | General Education Course | Elective Course |
| General Education Course | Elective Course | Innovation & Entrepreneurship Requirement | Elective Course |
| Elective Course | Elective Course | Elective Course | Elective Course |

Academic Policies

Transfer into Information Systems

Applications will be considered based on the following criteria:

- Completion of 15-112 Fundamentals of Programming and Computer Science with final grade of 'B' is required; a final grade of 'A' is preferred
- Completion of 15-121 or 15-122 is preferred, with a grade of 'B' or higher
- Strong record of academic performance at Carnegie Mellon (minimum QPA of 3.5 required)
- Personal statement (1-2 pages single spaced) on the following topic: *In your personal statement, please describe how your academic and career goals relate to the Information Systems Program. Please discuss your previous experiences that have led you to pursue the IS major, and how IS aligns with your future goals and aspirations. You may also discuss any other IS related experiences (e.g. internships, course projects, research, co-curricular experiences, etc.) or relevant coursework.*
- Interview with an IS Academic Advisor: IS advisor appointments should be made with the appropriate advisor (based on student last name) via the links on the advising page (<https://cms-staging.andrew.cmu.edu/information-systems-4/current-students/advising.html>) and should be completed by the deadline set forth for the current semester.
- Sample course plan through graduation (4th semester applicants only) When making your plan, we strongly recommend utilizing Stellar. The only Dietrich General Education course that will be waived is the Grand Challenge Seminar.

Application (<https://forms.gle/9XFDDy31avh8LW326/>) materials must be submitted no later than the last day of classes of the fall or spring semester. Students admitted into the IS Program will be officially declared in the semester following their application to the IS Program. If admitted, students will be declared as an IS major prior to the start of the following semester. All internal transfer students will be required to take 67-200: IS Research Colloquium during the first fall semester of their IS enrollment.

Students interested in applying for transfer to the Information Systems major should contact an IS Academic Advisor (<https://cms-staging.andrew.cmu.edu/information-systems-4/current-students/advising.html>) for information regarding availability, application procedures, and deadlines.

RANDY S. WEINBERG, Teaching Professor Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1998–

Double Counting of Courses

"Double Counting" refers to instances when a course taken to fulfill one requirement counts simultaneously toward a requirement in another major or minor program. Double Counting is permitted in the Dietrich College on a very limited basis. Information Systems students may double count no more than two courses towards an additional major and one towards a minor. There is no restriction on double counting for courses satisfying the Dietrich College General Education requirements and IS Prerequisite courses. Students must also adhere to any policy restrictions on double counting enforced by the academic department of the student's additional major or minor.

Course Repeats

Per university policy, when a course is repeated, all grades will be recorded on the official academic transcript and will be calculated in the student's QPA. This is the case regardless if the first grade for the course is a passing or failing grade.

Undergraduate students who wish to repeat a course already passed must obtain approval from the student's Dean or Department Head. When a student takes a course they already passed, only one set of units will count towards graduation requirements.

Faculty

MOHAMMAD AAZAM, Assistant Teaching Professor – Ph.D., Kyung Hee University ; Carnegie Mellon, 2022–

CHADI AOUN, Teaching Professor – Ph.D., Univeristy of New South Wales; Carnegie Mellon, 2015–

HOUDA BOUAMOR , Associate Teaching Professor – Ph.D., Paris-Sud University ; Carnegie Mellon, 2012–

ANIS CHARFI, Associate Teaching Professor – Dr.Ing., Technische Universitat Darmstadt; Carnegie Mellon, 2015–

SUSAN HAGAN, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

C.F. LARRY HEIMANN, Teaching Professor – Ph.D., Washington University (St. Louis); Carnegie Mellon, 1998–

SHIHONG HUANG, Teaching Professor – Ph.D., University of California, Riverside; Carnegie Mellon, 2023–

NAAMA ILANI-TZAR, Assistant Teaching Professor – Ph.D , Ben-Gurion University of the Negev; Carnegie Mellon, 2023–

DIVAKARAN LIGINLAL, Teaching Professor – Ph.D., University of Arizona - Tucson; Carnegie Mellon, 2009–

SELMA LIMAM MANSAR, Teaching Professor Emeritus – Ph.D., National Polytechnic Institute of Grenoble; Carnegie Mellon, 2007–

JOSEPH S. MERTZ, Faculty Director, Teaching Professor (joint Appointment with Heinz College) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997–

SARA MOUSSAWI, Associate Teaching Professor – Ph.D. , City University of New York; Carnegie Mellon, 2016–

DANIEL PHELPS, Area Head, Information Systems Qatar and Associate Teaching Professor – Ph.D., Florida State University; Carnegie Mellon, 2007–

JULIA POEPPING, Associate Director of Partnership Development – Masters, University of Pittsburgh ; Carnegie Mellon, 2019–

JERIA QUESENBERRY, Teaching Professor & Dietrich College Associate Dean of Faculty – Ph.D., Pennsylvania State University; Carnegie Mellon, 2007–

RAJA SOORIAMURTHI, Teaching Professor – Ph.D., Indiana University; Carnegie Mellon, 2007–

XIAOYING TU, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2020–

SAVANID (NUI) VATANASAKDAKUL, Associate Teaching Professor – Ph.D., University of New South Wales; Carnegie Mellon, 2018–

The Major in Information Systems Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

67-100 Information Systems First Year Colloquium

Fall: 1 unit

This IS Colloquium will provide a broad introduction to the Information Systems Program, an exciting program newly joint between Carnegie Mellon's Dietrich College and Heinz College. The IS Colloquium is open only to first-year IS students and is led by an IS academic advisor who facilitates discussions on the field of IS, the program curriculum, and careers, in addition to co-curricular experiences such as internships and study abroad. Because the flexible nature of the IS program encourages students to explore their own interests, we place an emphasis on highlighting a variety of areas within the field of IS. Guest lecturers will include leaders in IS research including Dietrich and Heinz faculty and IS alumni. Additional speakers include the IS career consultant and various campus representatives. Discussions will include students' progress in their first semester, as well as guidance in course planning, creating student Spring semester class schedules, and their overall four-year plan.

67-200 Information Systems Research Colloquium

Fall: 1 unit

The Information Systems Research Colloquium will educate students on research opportunities both in IS and beyond. By the end of the course, students should be able to: · Articulate what undergraduate research looks like at Carnegie Mellon University, and particularly identify the breadth of research opportunities in the field of Information Systems · Demonstrate how to communicate with faculty whose work aligns with individual interests · Describe several career and continuing education opportunities for Information Systems students The Information Systems Research Colloquium is open only to sophomore IS student as well as recent transfer students and is led by an IS academic advisor who facilitates discussions on the various research topics both through IS and other campus constituents.

67-204 Blockchains in Industry

All Semesters: 3 units

Industry experts characterize blockchains as breakthrough technology that has the same transformative power as that of the Internet. Blockchains have the potential to solve a variety of problems that benefit from a decentralized model of trust. This course will help students understand fundamental blockchain concepts and develop industry case studies of blockchain applications to finance, insurance, energy, healthcare, real estate, etc.

67-206 Information Systems Community Engagement

Fall and Spring: 6 units

This course is designed to provide an experiential learning experience to students in the IS program. Students will develop an iterative testing model to improve and conduct CMU Information Systems outreach program to Pittsburgh Public School. Students will engage with the community, have conversations with community partners and educators, and demonstrate knowledge of civic engagement, cultural identity, and diversity/inclusion. Experiential learning through engagement in the Pittsburgh Public Schools community will help CMU students make an impact on younger students, inspiring them to potentially pursue CMU IS or other interdisciplinary technology careers.

67-220 Digital Accessibility - Ensuring Universal Access to the Information Society

Fall: 9 units

Digital accessibility addresses a user's ability to easily access an electronic document, a website, or a computer application unhindered by visual, auditory, motor or cognitive impairments or temporal disabilities arising from age, illness etc. Students who takes this course will gain a deep understanding of the diverse problems faced by people with disabilities in their interactions in a digital space and how the use of assistive technologies help them surmount the related accessibility barriers (CT1 and CT3). They will learn about inclusive design principles and how to author content with consideration of design decisions that impact digital accessibility. Besides gaining an understanding of user-centered design principles, the students will learn how to apply Web Content Accessibility Guidelines (WCAG) to design and develop a website (CT2). To cap it, students will learn how to test, evaluate and report conformance of a website with usability principles and accessibility standards. (CT3)

67-240 Mobile Web Design & Development

Fall and Spring: 9 units

The Mobile Web Design and Development course provides a solid web design and development foundation focusing on responsive, user-centered design, and client-side components. Throughout the course, students work with HTML5, CSS3, Twitter Bootstrap, and JavaScript, and learn how the various web components function together. The course utilizes a hands-on approach to guide students through learning and understanding the design and development process. In this course, students work on in-class activities, individual assignments and a group project with a client using the current standards and best practices of web design and development. This course is primarily designed for students with minimal technical experience. By the end of the course, students will be able to plan, design, and implement a basic functioning mobile website/ app. Prerequisites: 15-110 Min. grade C or 15-112 Min. grade C or 15-104 Min. grade C

67-250 The Information Systems Milieux

Spring: 9 units

Information systems (IS) are changing work practices, reshaping organizations, transforming cultures, and giving new meaning to the ways we see the world. This course is designed to help students understand the role of IS in the enterprise and the means by which these systems are created, utilized and maintained. The course will focus on enterprise information architecture including the components of enterprise strategy, business, application, information, and infrastructure layers. This course provides not only a framework for understanding information systems, but also a language to identify their dynamic complexities and interdependencies.

67-262 Database Design and Development

Fall: 9 units

Data driven decision making is a core process of organizations. In this class students will study the principles of database management systems, their design, and development. Recent alternatives to the classical relational model will also be examined.

Prerequisites: 15-122 or 15-112 or 15-121

67-265 Design Fundamentals: Shaping Interactions and Experiences

Fall: 9 units

This course offers hands-on experience based on theoretical grounding linked to fundamental design practices. The first fundamental idea is stakeholders need an interesting and organized pre-task environment as a precursor to engaging with a task. A pre-task environment is one that invites stakeholders to engage with and stay in a designed space because they can see that they will enjoy performing tasks that meet their goals. This useful, usable, and desirable task environment is developed by exploring compositional guidelines, color theory, and basic typography. With pre-task knowledge in hand, students explore meaning-making that emerges through the synthesis of image, word, and typeface as they design and prototype interactive solutions to problems that real users face, employing user studies and usability evaluations to create effective solutions.

67-272 Application Design and Development

Spring: 12 units

This course provides students with the concepts and techniques to design and develop software applications, and to understand the design process. Students will learn the importance of user-centered design and will develop a prototype of a web application as a course project. In the process of developing the application, students will learn how to design and create relational databases, how to acquire competency in new programming languages quickly, how to use the Model-View-Controller pattern to develop software applications, how to ensure technical quality in software development, and how to apply principles of user-centered design. This course is a required professional core course and is open only to sophomores and juniors in the IS major.

Prerequisites: (15-122 or 15-121) and 67-262

67-279 Introduction to Geographical Information Systems

Intermittent: 6 units

Geographical Information Systems (GIS) allow us to visualize information that uses location. Through displaying layers of information in computer generated maps, we can see, analyze, understand and explore spatial patterns and relationships in new and novel ways. People in many different fields use Geographical Information Systems in their work: for visualizing the environment, human development, demographics, traffic and transportation, public health and many more. In this course, students will learn the basics of GIS through hands-on experience with popular mapping tools. Sources of data, principles of coordinate and projection systems and elementary geo-analysis techniques will be included. Upon completion of the course, students will have the background to begin using GIS techniques in their own areas of interest and will be prepared for further study in advanced GIS courses.

67-285 Across the Universe from Intelligent Agents to Users

Spring: 9 units

The goal of this course is to introduce students to how intelligent agents and similar systems impact and are perceived by users. In this course, we explore different dimensions relating to intelligent agents' design, usability, and user perceptions such as humanness, trust, privacy, bias, human values, emotions, and so on. To do so, we review research articles at the intersection of Information Systems, Psychology and Artificial Intelligence. The course aims to introduce students to the research process and equip them with the necessary tools to design and explore research questions that address pressing issues in the realm of user-agent interaction.

67-306 Management of Computer and Information Systems

Spring: 6 units

The course provides the overall knowledge of how Information Technology departments are managed in organizations of all sizes. It is about the technology people, the necessary best practice processes, and how innovation occurs transforming organizations in the way they operate and compete.

67-309 Special Topics: Information Assurance and Security

Fall: 6 units

Special Topics: Information Assurance is an introduction course for Information Systems students that focuses on information security concepts. This course will be a broad introduction to many aspects of information security that affect computer systems, your everyday life on the internet, your activities - and those of others, and the practices of all organizations using and building information systems. You will learn an introduction to the practice of securing information systems, how organizations manage risk to their information assets, what threats there are to the security of an information systems, strategies for organizational resilience, applicable US cyber laws, and how organizations respond to real incidents. You will hear about some of the major cyber incidents that have shaped the way security is performed by organizations on the internet today, and you will participate through class discussions and homework analyzing important recent cyber issues, real incidents, and internet-scale events. By the end of the class you will be able to analyze systems for security using the language of security professionals and analyze the implications of real world attacks on security systems by applying core information security concepts.

Prerequisites: 15-110 or 15-112

67-319 Global Technology Consulting Groundwork

Spring: 3 units

This course is by invitation only for participants in the Technology Consulting in the Global Community program. For information on the program and how to apply, see URL below.

Course Website: <http://cmu.edu/tcingc>. (<http://cmu.edu/tcingc.html>)**67-328 Full-Stack Application Development**

Fall: 9 units

Web 2.0, Mashups, Mobile Apps, and Cloud Computing are just a few of the new terms people are using to describe emerging technologies for building complex, distributed applications. Protocol standards, web services, open-APIs, increasingly more powerful mobile devices, and the Internet have enabled new possibilities for weaving complex applications using globally-distributed data and computing resources. Application development has largely left any single computer, and is distributed across a wide range of hardware and software platforms. This class will explore these developing technologies and models for structuring their complexity, while building projects that go from mobile to the cloud. Prerequisite: 67-272 (with "C" or higher) or permission of instructor.

Prerequisites: 67-272 Min. grade C or 67-240 Min. grade C

67-329 Contemporary Themes in Global Systems

Fall: 9 units

Globalization and outsourcing of information systems (IS) is a mainstay of the business environment. The decision to outsource software services to providers in distant places has many risks and thus careful management of critical success factors is essential. Likewise, products and services are being developed and delivered by teams of people in diverse locations working together. Management of these sourcing models and human capital relationships will be an increasingly important skill for students expecting to fully participate in the emerging IS marketplace of the 21st century. This course introduces the effective fundamentals of global project management and the mechanics of sourcing arrangements including offshore outsourcing. Students will also examine the effects of human diversity and cross-cultural considerations in the creation, use and management of information systems.

67-331 Technology Consulting in the Global Community

Fall

This course is only for participants in the Technology Consulting in the Global Community program. Admitted ONLY BY Permission of Instructor

67-338 Information & Grid Design

Fall: 9 units

Whether you create, oversee, or want practice solving problems through grid systems for websites, responsive applications, slide presentations, or data visualizations, this course provides the skills and perspective needed to communicate in grid environments: a synthesis of content, structure, and interaction. Grids emerged to address content/structure needs linked to print production, leaving opportunities to fully explore how they can better help stakeholders in interactive environments. As we explore this space, specific skillsets will include: developing a better understanding of visual composition through the grid, using the vocabulary of communication and information design in critique, manipulating typographic variables to create readable documents, learning approaches to invention using image, text, and amp; typography, creating simple to complex grid structures, developing skills in Illustrator, Photoshop, and Adobe XD, adapting simple prototypes to HTML/CSS through basic Bootstrap.

67-345 Power, Leadership, and Networks in Organizations

Spring: 6 units

This course is designed to improve your effectiveness as a manager by introducing you to frameworks for understanding power and leadership through the lens of networks. Organizations are political institutions, and effectively mobilizing resources to get things done is essential if a manager is to be effective in their job. Specifically, we focus on what power is, how it is acquired and how to use it to accomplish personal and organizational goals. Managers and members of organizations have different interests and resources. They are interdependent. When interdependent organizational actors with different interests need to attain certain goals, this can not be done without working with and through others. Consequently, leaders need to find ways to influence others to act in ways which they might not choose to do otherwise. We discuss how these political actions are associated with networking behaviors and how social relationships co-evolve power dynamics in organizations. This course will introduce you to t and ways to apply the knowledge to particular situations through class discussion, case analysis, and in-class activities.

67-346 Blockchain Fundamentals

Intermittent: 6 units

In this course, we will dig into the blockchain technology. We will learn from the basic, single-purpose blockchain (such as for Bitcoin) to general purpose blockchain (which includes a range of use-cases). The course will cover a broad spectrum of blockchain technology, different consensus algorithms, its various real-world use-cases with an eye on developing our own blockchain. We will also understand various challenges with this technology, and a case-study that covers implementation in Python. This would be an interactive course and the students are expected to share ideas and their thoughts.

67-348 Black Mirror - Cultural Representations of Technology

Fall: 9 units

Advances in technology raise a variety of fascinating ethical, cultural, and societal questions often resulting in uncertainties and unanticipated dilemmas. This course provides students opportunities to explore how cultural representations of technology are reflected in society and inform continued technical advancements. Using episodes from *Black Mirror* - a British anthology television series created by Charlie Brooker - we will explore the depictions of technology and society. Discussions of episodes will be supplemented by popular, critical texts and academic articles. This course will challenge students to think critically about technological change and acquire a more sophisticated understanding of the political, economic, and cultural considerations that underlie technological development. Students will engage critically and constructively in key debates that shape the future of the technology, through in-class discussions, presentations, and colloquia.

67-364 Practical Data Science

Spring: 9 units

From empirical, to theoretical, to computational science, we are at the dawn of a new revolution and #8212;a fourth paradigm of science driven by data. Like archaeological remnants, data, by its very nature, is a marker of what happened in the past. How can data be used to better understand this past and what is happening in the present? How can data be leveraged to forecast what will happen in the future? Better still, how can data be used to mold what should happen in the future? In this course we will study descriptive, predictive, and prescriptive methods by which data can be used to gain insight and inform actions of people and organizations. The real excitement of data science is in the doing. This is an application oriented course requiring skill in algorithmic problem solving. We will use Python based data science tools. While prior programming experience with Python will be helpful the course will strive to be self-contained. If you have not programmed in Python before, you need to be comfortable programming in some language (e.g., Ruby, R, Java, C++) and will need to come up to speed with the Pythonic way of problem solving.

Prerequisites: (36-201 Min. grade C or 36-200 Min. grade C) and 15-112 Min. grade C

67-367 Information Warfare

Intermittent: 9 units

In this course, we will examine information warfare through technical as well as strategic, operational, and tactical employment perspectives. This course will address historical aspects of military deception, electronic warfare, computer network operations, operational security, and psychological operations

67-373 Information Systems Consulting Project

Spring: 12 units

In this course, students design and implement a usable information system for a client. The client may be affiliated with the university, government, business, or non-profit agency. Students will be assigned to teams to work on these projects, and will produce operational, fully documented and tested, computer-based information systems. The projects will be supervised by CMU faculty and, when possible, by project clients.

Prerequisite: 67-272

67-380 Information Systems Security

Intermittent: 9 units

This course is an introduction to information systems security for the IS student. The course will introduce the student to fundamental concepts in information system security, including operational issues, planning, and design. Topics will include confidentiality, integrity, and availability; risk; access controls and access control frameworks; security policies; authentication strategies and issues; auditing; using cryptography; security design issues; controlling information flows; malicious logic; and applying security principles

67-390 Independent Study in Information Systems

Fall and Spring

Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, or 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade. This is available by Special Permission.

67-391 Independent Study in Information Systems

Fall and Spring

Independent studies are opportunities to engage in research with an IS faculty member to advance your learning in certain areas of interest. Information Systems students may enroll in independent study for 3, 6, 9, 12 units of academic credit by obtaining an IS faculty sponsor who will oversee the academic component of the coursework, monitor progress, and assign a final grade.

67-393 Guided Research in Information Systems

All Semesters

This course is for team-based research with an IS faculty member. Upon prior approval by the faculty member, students may enroll for 3, 6, 9, or 12 units.

67-404 Blockchain Applications

Intermittent: 9 units

In this course, we will dig into the blockchain technology. We will learn from the basic, single-purpose blockchain (such as for Bitcoin) to general purpose blockchain (which includes a range of use-cases). The course will cover a broad spectrum of blockchain technology, different consensus algorithms, its various real-world use-cases - with an eye on developing our own blockchain. We will also understand various challenges with this technology, and a case-study that covers implementation in Python. This would be an interactive course and the students are expected to share ideas and their thoughts.

67-410 Clinical Data Science

Intermittent: 9 units

This course is designed as an introductory course in Critical Care Data Science, providing an introduction to the tools and techniques of data science, specifically focused on clinically relevant critical care. Electronic Medical Records; Common Data Models for Clinical Data; SQL Querying; Computational Phenotyping; Common Machine Learning Techniques (Supervised; Unsupervised; Reinforcement Learning); and Reporting Clinical Data Science Research.

67-415 Cyber Ethics and Regulation

Intermittent: 9 units

This course investigates the ethical and regulatory implications of technology by adopting a four-dimensional framework focused on Privacy, Accuracy, Property, and Accessibility (PAPA Framework). It examines legal rights and corresponding duties and responsibilities of stakeholders. The course delves into established and emergent themes including cyber law, surveillance, dis/misinformation, artificial intelligence, intellectual property, cybersecurity, and organizational policy. Its primary focus is on social, behavioral, and legal implications of technology, assessed from multiple perspectives pertaining to individuals, organisations and societies.

67-425 Special Topics - Capstone course in Digitalization

Intermittent: 9 units

Most organizations including your future employers use enterprise systems to run their business processes such as sales, procurement, and production. This course discusses key business processes in organizations and the role, functions and technical foundations of enterprise systems such as Enterprise Resource Planning (ERP) systems and Customer Relationship Management (CRM) systems. Through hands-on use of enterprise systems in multiple case studies, the students will become familiar with the key concepts in such systems and demonstrate practical knowledge on how such systems allow organizations to run end-to-end business processes such as order-to-cash or make-to-order. The course also addresses the lifecycle of enterprise systems' projects and their various phases such as selection, implementation, operation and maintenance.

67-426 Special Topics - Capstone course in Data Science

Intermittent: 9 units

TBA

67-443 Mobile Application Design and Development

Fall: 12 units

This course provides students with the concepts and techniques to design and develop innovative mobile applications. Students will develop a series of smaller mobile applications in weekly lab sessions (using either iOS or Android frameworks). In addition, student teams will build a larger mobile application, as part of a semester-long project, that fills a demand not effectively met in the current market. In the process of developing these applications, students will gain a strong understanding of mobile application development, mobile-centered design, the process of creating and testing innovative application design, and larger principles of software engineering. In weekly labs, students can choose either the Swift/iOS or Kotlin/Android track to complete course work, but lectures will primarily use Swift to illustrate larger points of software architecture and engineering. This course is open only to seniors in the IS major.

Prerequisite: 67-272 Min. grade C

67-490 Practicum in Information Systems

Intermittent

This course is offered only at Carnegie Mellon's campus in Qatar. The practicum in information systems allows students interested in applying skills acquired in the field of information systems in the context of a working environment. Students will complete a project and be accountable to a stakeholder that is external to their program of study. They may shadow and observe practices in the field of information systems, and also perform tasks as assigned. A hands-on experience is expected. By completing this course, students practice desirable skills for employability, such as time management, project management, team work, and professional development.

67-505 Information Systems Internship

Fall and Spring

Practical experience in Information Systems.

67-728 Full-Stack Application Development

Fall: 9 units

Web 2.0, Mashups, Mobile Apps, and Cloud Computing are just a few of the new terms people are using to describe emerging technologies for building complex, distributed applications. Protocol standards, web services, open-APIs, increasingly more powerful mobile devices, and the Internet have enabled new possibilities for weaving complex applications using globally-distributed data and computing resources. Application development has largely left any single computer, and is distributed across a wide range of hardware and software platforms. This class will explore these developing technologies and models for structuring their complexity, while building projects that go from mobile to the cloud.

67-738 Information & Grid Design

Fall: 9 units

Whether you create, oversee, or want practice in solving problems through grid systems for websites, responsive applications, slide presentations, or data visualizations, this course provides the skills needed to communicate using the interplay of image, text, and typography in grid environments.

67-743 Mobile Application Design and Development

Fall: 12 units

This course provides students with the concepts and techniques to design and develop innovative mobile applications. Students will develop a series of smaller mobile applications in weekly lab sessions (using either iOS or Android frameworks). In addition, student teams will build a larger mobile application, as part of a semester-long project, that fills a demand not effectively met in the current market. In the process of developing these applications, students will gain a strong understanding of mobile application development, mobile-centered design, the process of creating and testing innovative application design, and larger principles of software engineering. In weekly labs, students can choose either the Swift/iOS or Kotlin/Android track to complete course work, but lectures will primarily use Swift to illustrate larger points of software architecture and engineering.

Prerequisite: 95-712

Carnegie Mellon Institute for Security and Technology

Audrey Kurth Cronin, Director, Trustees Professor of Security and Technology

Location: Posner Hall 385A

www.cmu.edu/cmist/ (<http://www.cmu.edu/cmist/>)

Carnegie Mellon University (CMU) launched a major new interdisciplinary institute, the Carnegie Mellon Institute for Security and Technology (CMIST) (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>), in 2023. CMIST is a university-wide initiative devoted to the wise development, use, and governance of new and emerging technologies that are changing the national and international security landscape.

The home for Carnegie Mellon University's (CMU) study of Political Science and International Relations, CMIST hosts academic programs that enable students to wrestle with a wide range of issues, including the future of democracy, the relationship between technology and politics, the drivers of war and peace, domestic politics across countries, and the formulation of effective foreign policies. Our students and faculty investigate issues in security and technology, grand strategy and national security, cybersecurity and international conflict, military strategy and doctrine, the politics of key regions of the world, international political economy and economic policy, representation and voting rights, climate change and development, repression and human rights, international law and diplomacy, political psychology and public opinion, and social change and revolution. Our graduates embark on a variety of careers in government, law, public policy, intelligence, national defense, consulting, international development, and more.

CMIST is where we address the challenges of new and emerging technologies through a political science lens, focused on maximizing the benefits and reducing the risks to human beings, national security, and global stability. Taking advantage of the intellectually rich Carnegie Mellon setting, CMIST draws upon the university's strengths in computer science and engineering and its distinctive tradition of collaborative, cross-university, cross-disciplinary research. CMU is ranked #1 in the subfields of artificial intelligence, computer engineering, cybersecurity, information systems, and software engineering. It has leading research institutes in areas such as robotics, machine learning, natural language technologies, human-computer interaction, engineering and public policy, and public policy and management—all designed to reach across disciplinary boundaries to solve key problems and address the highest-priority challenges facing humanity. CMIST ties Carnegie Mellon's strengths in building new technologies to crucial questions of strategy, security, ethics, and policy, with a social science approach.

In its focus on Political Science and International Relations, CMIST offers the following undergraduate degree programs and initiatives:

- o BS International Relations and Political Science (primary and additional major);
- o BS Economics and Politics (primary and additional major);
- o International Relations and Political Science Minor;
- o Cybersecurity and International Conflict Minor;
- o Military Strategy and International Relations Minor;
- o Politics and Public Policy Minor; and
- o The Carnegie Mellon University Washington Semester Program.

Bachelor of Science in International Relations and Political Science

Audrey Kurth Cronin, *Director, Trustees Professor of Security and Technology*

acronin@andrew.cmu.edu, Posner Hall 385A

Emily Half, *Deputy Director*

ehalf@andrew.cmu.edu, Posner Hall 391, 412-268-7082

<http://www.cmu.edu/cmist/> (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>)

The Bachelor of Science in International Relations and Political Science (IRPS) is for students who want to learn how to think systematically and develop foundational knowledge about international and domestic politics. It is an interdisciplinary major that is rooted firmly in political science and draws on strengths and insights from decision science, economics, history, modern languages, and other fields. BS IRPS students wrestle with a wide range of issues including the future of democracy, the relationship between technology and politics, the drivers of war and peace, domestic politics across countries, and the formulation of effective foreign policies. IRPS graduates embark on a variety of careers in government, law, public policy, intelligence, national defense, consulting, international development, and more.

Core disciplinary courses for the IRPS major establish a strong foundation in the study of political science and enable students to better understand the workings of political institutions, political behavior across countries, the decision-making of political leaders, the making national and international policy, and prevailing challenges to the international system, among other topics.

Core methodology courses train IRPS students in the social science tools and communications skills needed to analyze and write persuasively about international relations and politics. Students pursuing an IRPS major learn to use a wide range of analytic tools including statistics and data science, qualitative analysis, game theory, and behavioral decision-making models as they study politics and strategy. Students also learn how to effectively communicate their analyses to affect public policy.

A rich set of electives allows students to investigate issues in security and technology, grand strategy and national security, cybersecurity and international conflict, military strategy and doctrine, the politics of key regions of the world, international political economy and economic policy, representation and voting rights, climate change and development, repression and human rights, international law and diplomacy, political psychology and public opinion, and social change and revolution.

Recognizing the importance of language and culture in understanding politics and international relations, students are required to complete the intermediate (200) level, or its equivalent, in a modern language other than English. Advanced-level study is strongly encouraged.

Open to all Carnegie Mellon undergraduates, the Carnegie Mellon University Washington Semester Program (CMU/WSP) (<https://www.cmu.edu/ips/cmuwsp/>) allows students to study politics and public policy, and to spend a semester interning in Washington, DC. Courses taken through CMU/WSP count toward the policy seminar core requirement and electives for the IRPS major.

Double Counting: Students may double count a maximum of four courses with another major or minor.

Curriculum

Disciplinary Core Courses

Students must complete all of the following disciplinary core courses.

| | | |
|-----------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| or 73-102 | Principles of Microeconomics | |
| or 73-103 | Principles of Macroeconomics | |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-450 | Policy Seminar | 6 |

Methodology Core Courses

Students must complete all of the following methodology core courses.

| | | |
|-----------|--|---|
| 84-250 | Writing for Political Science and Policy | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-267 | Data Science for Political Science | 9 |
| or 36-202 | Methods for Statistics & Data Science | |
| 84-369 | Decision Science for International Relations | 9 |

Language Requirement

Students are required to complete a course at the Intermediate II level or higher of a modern language other than English. Advanced level study is strongly encouraged. Students who successfully pass a language placement exam on campus, at the intermediate II level or higher, are required to take an advanced language course to satisfy the language requirement.

Electives

Students must complete 54 units (usually six courses) from the elective lists below. At least four courses (36 units) must be taken from the Carnegie Mellon Institute for Security and Technology (84-xxx). Most courses listed below are 9-unit courses, but some are fewer. When students choose courses offered for fewer than 9 units, they must remember that a minimum of 54 units is still required and thus plan to take one or more additional courses to fill out that minimum number. In other words, the key requirement is the number of *units* (54), not the number of *courses*.

CMIST Electives

| | | |
|--------|--|----|
| 84-200 | Security War Game Simulation | 6 |
| 84-252 | Briefing in the Policy World | 6 |
| 84-303 | International Human Rights | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-306 | Latin American Politics | 9 |
| 84-307 | Economic and Political History of Contemporary China | 9 |
| 84-310 | International Political Economy | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-313 | International Organizations and Law Taught in Washington, DC, through CMU/WSP | 6 |
| 84-315 | Political Economy of International Migration | 9 |
| 84-316 | Political Economy of Transatlantic Partnership | 9 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics Taught in Washington, DC, through CMU/WSP | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking Taught in Washington, DC, through CMU/WSP | 6 |
| 84-334 | The History and Practice of Economic Statecraft Taught in Washington, DC, through CMU/WSP | 6 |
| 84-335 | US China Relations Taught in Washington, DC, through CMU/WSP | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality Taught in Washington, DC, through CMU/WSP | 12 |
| 84-337 | Biomedical Science Research, Policy, and Governance Taught in Washington, DC, through CMU/WSP | 6 |
| 84-339 | Seminar in Public Policy Research Taught in Washington, DC, through CMU/WSP | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington Taught in Washington, DC, through CMU/WSP | 12 |
| 84-348 | Advocacy, Policy and Practice Taught in Washington, DC, through CMU/WSP | 6 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-360 | CMU/WSP: Internship Seminar Taught in Washington, DC, through CMU/WSP | 12 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |

| | | |
|--------|---|------|
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |
| 84-440 | Collaborative Research in Political Science | Var. |

Additional Electives

| | | |
|--------|---|----|
| 19-452 | EPP Projects II | 12 |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| 73-332 | Political Economy | 9 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 82-3xx | 82-3xx or 4xx Advanced Level Modern Language Class | |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |
| 88-411 | Rise of the Asian Economies | 9 |

NOTE: Some courses have additional prerequisites.

Sample four-year plan

These sample curricula represent a plan for completing the requirements for the B.S. in International Relations and Political Science. International Relations and Political Science (IRPS) students are encouraged to spend a

semester studying and interning in Washington, DC, through the CMU/WSP (<http://www.cmu.edu/ips/cmuwsp/>), and/or study abroad. The plan below demonstrates that a semester off-campus fits well into the curriculum. As with most majors in the Dietrich College, the IRPS major can be completed in as few as two years of undergraduate study, not that it must be. Students may declare the BS in International Relations and Political Science as early as the second semester of the freshman year and should consult frequently with the deputy director (see above) about their course of study. Please note that this is only a sample plan of study and not the only possible plan of study. The IRPS major and Dietrich College General Education curricula provide a high degree of flexibility in sequencing and coursework. Double counting between the major and the General Education requirements is unlimited. The plan below shows a very conservative view of double counting.

| First-Year | | Second-Year | |
|--|---|--|---|
| Fall | Spring | Fall | Spring |
| 84-104 Decision Processes in American Political Institutions | 84-110 Foundations of Political Economy | 84-226 International Relations | 84-267 Data Science for Political Science |
| 36-200 Reasoning with Data | 84-250 Writing for Political Science and Policy | 84-266 Research Design for Political Science | Language Course* |
| Grand Challenge Seminar | 84-275 Comparative Politics | Language Course* | General Education |
| First-Year Writing | Disciplinary Perspectives: Humanities | General Education | General Education |
| Language Course* | Language Course* | IRPS Elective | IRPS Elective |
| 99-101 Computing @ Carnegie Mellon | | | |

*If starting a Modern Language at the Elementary I level, four semesters of language study are required for the IRPS major. AP credit or a language placement exam may allow students to begin at CMU in a level higher than Elementary I and have fewer required semesters of language study.

| Third-Year | | Fourth-Year | |
|---|--------------------------|-------------------|-----------------------|
| Fall | Spring | Fall | Spring |
| 84-369 Decision Science for International Relations | CMU/WSP or STUDY ABROAD* | IRPS Elective | 84-450 Policy Seminar |
| IRPS Elective | Explore | IRPS Elective | IRPS Elective |
| General Education | Explore | IRPS Elective | General Education |
| General Education | Explore | General Education | Explore |
| Explore | Explore | General Education | Explore |

*All students are strongly encouraged to participate in the CMU/WSP (<http://www.cmu.edu/ips/cmuwsp/>) and/or in a study abroad program. Spring semester of the junior year is a popular semester to study off-campus. However, International Relations and Political Science majors may instead choose to participate in the CMU/WSP or study abroad in spring of sophomore year, fall of junior year, or fall of senior year. Students should consult the deputy director when planning their curricular program. **Students who participate in the CMU/WSP (<https://www.cmu.edu/ips/cmuwsp/>) will complete the Policy Seminar while studying in Washington, DC. Students who do not participate in the CMU/WSP will take the Policy Seminar in the spring of the senior year in Pittsburgh.

Additional Major

Students who elect International Relations and Political Science as an additional major must fulfill all of the requirements of the BS in International Relations and Political Science primary major.

Bachelor of Science in Economics and Politics

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries—an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (<https://www.cmu.edu/tepper/programs/undergraduate-economics/>) (UEP) and the Carnegie Mellon Institute for Security and Technology (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteofpoliticsandstrategy/www.cmu.edu/cmist/>) (CMIST). Students are equal members of both academic units and receive advising from

both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The BS in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

CMIST strengths lie in topics such as emerging technology, national security, and grand strategy. Economic policy is one facet of grand strategy, through which governments pursue domestic and international goals. It will enable students to understand economic statecraft from a broad perspective. This major will address key issues such as how multilateral economic institutions such as the IMF and World Bank use economic coercion. Whether coercion is successful or not depends not only on the levers of power but on also on variations in regime structures, alongside complex linkages in the international economy. For example, the viability of the “Euro Zone” depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure. In short, international economics affects everything from human rights practices to global compliance with climate change treaties.

Economics and Politics is available as both a primary and an additional major. The requirements are the same for both.

Curriculum

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Mathematics

Students must complete all of the following courses.

| | | |
|-----------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| or 21-112 | Calculus II | |
| 21-256 | Multivariate Analysis | 9 |
| or 21-259 | Calculus in Three Dimensions | |

Foundations (36 units)

Students must complete all of the following courses.

| | | |
|-----------|---|---|
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-275 | Comparative Politics | 9 |

***Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102**

Core (63 units)

Students must complete all of the following courses.

| | | |
|--------|---------------------------------------|---|
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |
| 84-226 | International Relations | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-310 | International Political Economy | 9 |

Communication (9 units)

Students must complete one course from the following list.

| | | |
|--------|---|---|
| 73-270 | Professional Communication for Economists | 9 |
| 84-250 | Writing for Political Science and Policy | 9 |

Electives (27 units)

Majors are required to take 27 units (three courses) from the elective lists below. At least one course (9 units) must be taken from Economics (73-xxx) and at least one course (9 units) must be taken from the Carnegie Mellon Institute for Security and Technology (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (<https://www.cmu.edu/ips/cmuwsp/>).

| | | |
|---|--|----|
| Economics Electives | | |
| 73-328 | Health Economics | 12 |
| 73-332 | Political Economy | 9 |
| 73-338 | Financial Crises and Risk | 9 |
| 73-352 | Public Economics | 9 |
| 73-353 | Financial Regulation in the Digital Age | 9 |
| 73-359 | Benefit-Cost Analysis | 9 |
| 73-365 | Firms, Market Structures, and Strategy | 9 |
| 73-421 | Emerging Markets | 9 |
| 73-427 | Sustainability, Energy, and Environmental Economics | 9 |
| International Relations and Political Science Electives | | |
| 84-200 | Security War Game Simulation | 6 |
| 84-252 | Briefing in the Policy World | 6 |
| 84-303 | International Human Rights | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-306 | Latin American Politics | 9 |
| 84-307 | Economic and Political History of Contemporary China | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-313 | International Organizations and Law <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-315 | Political Economy of International Migration | 9 |
| 84-316 | Political Economy of Transatlantic Partnership | 9 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-334 | The History and Practice of Economic Statecraft <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-335 | US China Relations <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-337 | Biomedical Science Research, Policy, and Governance <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-339 | Seminar in Public Policy Research <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-348 | Advocacy, Policy and Practice <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-360 | CMU/WSP: Internship Seminar <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |

| | | |
|--------|---|------|
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |
| 84-440 | Collaborative Research in Political Science | Var. |

Additional Electives

| | | |
|--------|--|---|
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 88-323 | Policy in a Global Economy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-419 | International Negotiation | 9 |
| 88-444 | Public Policy and Regulations | 9 |

CAPSTONE (15-21 units)

Students must complete all of the following courses.

| | | |
|--------|--|---|
| 84-450 | Policy Seminar | 6 |
| 73-497 | Senior Project or Senior Honors Thesis | 9 |

Note: Students in the BS in Economics and Politics who complete a Dietrich or Tepper Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

DOUBLE-COUNTING RESTRICTION

A maximum of four courses may double count with another major or minor.

SAMPLE Four Year Plan

These sample curricula represent a plan for completing the requirements for the B.S. in Economics and Politics. Economics and Politics students are encouraged to spend a semester studying and interning in Washington, DC, through the CMU/WSP (<http://www.cmu.edu/ips/cmuwsp/>), and/or study abroad. The plan below demonstrates that a semester off-campus fits well into the curriculum. Students may declare the BS in Economics and Politics as early as the second semester of the freshman year and should consult frequently with the Economics and Politics advisors about their course of study. Please note that this is only a sample plan of study and not the only possible plan of study. The Economics and Politics major and Dietrich College General Education curricula provide a high degree of flexibility in sequencing and coursework. Double counting between the major and

General Education requirements is unlimited. The plan below shows a very conservative view of double counting.

| First-Year | | Second-Year | |
|--|---------------------------------------|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 73-230 Intermediate Microeconomics | 73-240 Intermediate Macroeconomics |
| 36-200 Reasoning with Data | 73-103 Principles of Macroeconomics | 73-265 Economics and Data Science | 73-274 Econometrics I |
| 73-102 Principles of Microeconomics | 84-275 Comparative Politics | 84-226 International Relations | Communication Course (84-250 or 73-270) |
| 84-104 Decision Processes in American Political Institutions | First-Year Writing | 84-266 Research Design for Political Science | General Education |
| Grand Challenge Seminar | Disciplinary Perspectives: Humanities | 84-310 International Political Economy | General Education |
| 99-101 Computing @ Carnegie Mellon | | | |

| Third-Year | | Fourth-Year | |
|-------------------------------|-------------------------|-------------------------------|-----------------------|
| Fall | Spring | Fall | Spring |
| General Education | CMU/WSP or Study Abroad | 73-497 Senior Project | 84-450 Policy Seminar |
| General Education | Explore | General Education | General Education |
| General Education | Explore | Economics & Politics Elective | Explore |
| General Education | Explore | Economics & Politics Elective | Explore |
| Economics & Politics Elective | Explore | Explore | Explore |

Minor in Cybersecurity and International Conflict

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www.cmu.edu/cmist (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>)

The minor in cybersecurity and international conflict analyzes the past, present, and future role of cyber conflict and cybersecurity in international politics. Cyber attacks by nation-states and their proxies have an important impact upon conflict. The complexity and policy challenges of cyber-engagements is immense. This minor addresses the role of deterrence, dissuasion, and attribution in cyber conflict, while also studying the nuances of key components of modern warfare—from the security dilemma to escalation management.

Courses in this minor focus on the existing gaps in our understanding of cybersecurity and international conflict, such as whether cyberspace is offense or defense dominant (or over time fluid between the two), and which factors are important in determining the answer to this. Other relevant questions include how nation-states, their primary adversaries, and a bevy of nonstate actors engage online and in the virtual and information environments. Accordingly, the minor exposes students to basic technology concepts, methods of attack and defense, potential strategy and goals for cyber-engagement, and response and forensics for cyber-engagements.

Alongside conventional methods of warfare, cybersecurity has rapidly developed into a centerpiece of a state's ability to project power. As the United States and other emerging cyber powers craft and implement doctrine in this domain, there is likely to be a rapid increase in activity, from efforts to disrupt the online activities of global terrorist networks, to cybersecurity offense and defense in the Russia-Ukraine war, to near daily raids on foreign networks designed to cripple states' cyberweapons before they can be deployed. In addition, the impact of cyberattacks on critical infrastructure, theft of intellectual property, pervasive identity theft, and hacking of sensitive databases have accumulated, gradually wearing down civilian networks and achieving strategic effects over time.

In the shifting landscape of cyber capabilities, how will laws, authorities, and policies keep pace? What are the implications and consequences of actions that may be considered "short of war" by some countries but "above the threshold" of conflict by others? Will a more aggressive defensive posture with respect to cybersecurity inadvertently increase the risk of conflict with states that sponsor malicious hacking groups? What is the proper balance

between offense and defense in cybersecurity and how are cyber operations best integrated into a country's overall military strategy?

Unlike other kinds of conflicts, attribution of attacks presents significant challenges. Indeed, in many cases, it can be difficult to determine whether the attacker is a nation-state, a nonstate actor, a criminal gang, or a lone hacktivist. Investigators must combine technical and traditional methods to identify potentially responsible parties and to understand their intent. If the aggressor's identity cannot be confirmed, how can a counterattack be launched? Some attackers may seek to mount "false flag" attacks and deception, for example, that misdirect defenders to counter-attack in the wrong direction.

Additionally, what are appropriate responses to attacks made on civil infrastructure and private business operations, such as in the areas of financial services, transportation, energy, entertainment, and health care? In other words, what are the appropriate rules of engagement for national systems, infrastructural systems, businesses, and individuals? When, for example, is a counterattack or a "kinetic" response permissible?

These questions have major implications for the study of war and peace. Those who seek to start a war may be harder to find and their motives more difficult to discern. The cybersecurity and international conflict minor tackles the social-scientific dimensions of cybersecurity with a focus on the implications of the cyber age for modern statecraft, warfare, elections (local, state, and national), and domestic and international politics.

CURRICULUM 60 units

Foundational Course

Students must take one of the following foundational courses (9 units):

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |

Core Courses

Students must take all of the following core courses (24 units):

| | | |
|--------|---|---|
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-405 | The Future of Warfare | 9 |

Elective Courses

Students must take three courses from the following list of elective courses (27 units). At least one course (9 units) must be taken from the Carnegie Mellon Institute for Security and Technology and have an 84-number.

| | | |
|--------|---|------|
| 84-200 | Security War Game Simulation | 6 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-319 | Civil-Military Relations | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-334 | Usable Privacy and Security | 9 |
| 17-702 | Current Topics in Privacy Seminar | 3 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |

| | | |
|--------|---|----|
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 95-444 | Cybersecurity Policy and Governance | 12 |

Students are permitted to double count a maximum of two courses between the minor in Cybersecurity and International Conflict and another major or minor.

Minor in International Relations and Political Science

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The International Relations and Political Science (IRPS) minor examines international relations, comparative politics, and domestic politics from the discipline of political science. It analyzes the role of politics at the national, regional, international, and transnational levels; examines political and institutional arrangements within and among these levels; and investigates current issues relevant to the field of international relations.

The IRPS minor studies the ways in which leaders construct foreign and national security policy; the impact of domestic and international forces on states' security and economic policies; and the significance of alliances, coalitions, and international institutions for world politics. The minor emphasizes the importance of political institutions, decision making by leaders in shaping policy, and contemporary challenges to the international system.

A maximum of two courses may double count between the minor in International Relations and Political Science and another major or minor.

Curriculum

63 units

Core Courses

Students must take all of the following core courses (36 units):

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| | or 73-102 Principles of Microeconomics | |
| | or 73-103 Principles of Macroeconomics | |
| | or 73-104 Principles of Microeconomics Accelerated | |

Electives

Students select three courses (27 units) from the elective lists below. Two courses (18 units) must be taken from the Carnegie Mellon Institute for Security and Technology (CMIST) and have an 84-number.

CMIST Electives

| | | |
|--------|---|---|
| 84-200 | Security War Game Simulation | 6 |
| 84-252 | Briefing in the Policy World | 6 |
| 84-303 | International Human Rights | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-306 | Latin American Politics | 9 |
| 84-307 | Economic and Political History of Contemporary China | 9 |
| 84-310 | International Political Economy | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-315 | Political Economy of International Migration | 9 |
| 84-316 | Political Economy of Transatlantic Partnership | 9 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |

| | | |
|--------|--|------|
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |
| 84-440 | Collaborative Research in Political Science | Var. |

Additional Electives

| | | |
|--------|---|----|
| 19-452 | EPP Projects II | 12 |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| 73-332 | Political Economy | 9 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |

| | | |
|--------|---|---|
| 80-249 | AI, Society, and Humanity | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 82-3xx | 82-3xx or 4xx Advanced Level Modern Language Class | |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |
| 88-411 | Rise of the Asian Economies | 9 |

Minor in Military Strategy and International Relations

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www.cmu.edu/cmist (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>)

The minor in Military Strategy and International Relations offers Carnegie Mellon undergraduates a course of study focusing on military strategy and the current national security landscape, including how cybersecurity and artificial intelligence influence national security decision making, and the full range of strategic challenges facing future leaders.

While the minor is open to all CMU undergraduates, it is particularly appropriate for CMU students embarking on the Reserve Officer Training Corps (ROTC) program as well as those interested in pursuing defense-related careers. CMU typically has several dozen ROTC students annually, spread throughout the university, along with many others who are interested in defense and strategy issues. Many students major in STEM fields, where they learn valuable technical skills but are exposed to little of the wider strategic context facing military leaders and decision-makers or to the political and institutional frameworks in which they operate. This minor is designed to complement that study and fill that gap.

In short, the Military Strategy and International Relations minor offers future military and defense leaders insight into the national and international strategic challenges they will navigate in the future.

The Military Strategy and International Relations minor will teach future leaders how of diplomacy, development, and defense intersect. It will engage students in the whys and hows of national strategy, military planning, and the future of warfare. In addition, the minor emphasizes the political, legal, and institutional systems that shape military affairs, with core courses on the topics of civil-military relations, military strategy, governance, diplomacy, and policy decision making. Finally, the minor stresses the use of cutting-edge analytical and social science methods to prepare students for advanced training, study, and government or military service in national and international security.

Curriculum

60 units

Core Courses

Students must take the following core courses (33 units):

| | | |
|------------------------|--------------------------------------|---|
| Military Strategy | | |
| 84-328 | Military Strategy and Doctrine | 9 |
| Governance | | |
| 84-319 | Civil-Military Relations | 9 |
| Diplomacy (select one) | | |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| Policy | | |
| 84-450 | Policy Seminar | 6 |

Electives

Students must complete a total of 27 units (typically three courses) from the following list of courses. At least 9 units must be taken from the Carnegie Mellon Institute for Security and Technology (CMIST) and have an 84-number.

| | | |
|-----------|--|---|
| Electives | | |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-200 | Security War Game Simulation | 6 |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-313 | International Organizations and Law | 6 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy <small>If not used as a core course, course may count as an elective.</small> | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-362 | Diplomacy and Statecraft <small>If not used as a core course, course may count as an elective.</small> | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-405 | The Future of Warfare | 9 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 32-201 | Leadership & Management | 9 |
| 32-310 | Evolution Of Warfare | 9 |
| 32-402 | Leadership and Ethics | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-268 | World War I: The Twentieth Century's First Catastrophe | 9 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |

Students may double count a maximum of two courses (18 units) with another major or minor. Unlimited double counting is permitted with general education requirements.

Minor in Politics and Public Policy

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www.cmu.edu/cmist (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>)

Rooted in the discipline of political science, the minor in Politics and Public Policy investigates US public policy issues and other matters of domestic politics while providing students hands-on and practical learning experiences. Students pursuing the Politics and Public Policy minor must participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (<https://www.cmu.edu/ips/washington-dc-semester-program/>) for one semester during their undergraduate years.

The CMU/WSP, sponsored by the Carnegie Mellon Institute for Security and Technology (CMIST), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Undergraduates from any course of study at the university may participate in the program. Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field

of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty.

From embassies to nongovernmental organizations, think tanks to advocacy organizations, government agencies to congressional offices, and consulting firms to media outlets, Washington, DC, is the center of US political, international, and public policy activities. Students in the program come into direct contact with policymakers, Congressmen, think tank leaders, and business leaders, and through hands-on experience learn about the most pressing policy issues of the day.

Through this experiential learning program, CMU/WSP participants develop professional and networking skills, explore how coursework connects to the real world, learn to give and receive constructive feedback in the workplace and classroom, and intentionally reflect on their learning and growth. Every CMU/WSP student is paired with a Washington, DC- based alumni mentor to share career advice and tips about life in DC. CMIST also sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and domestic policy decision making.

Curriculum 66 units

Core Seminars

Students must take the following courses while participating in the CMU/WSP (24 units):

| | | |
|--------|-----------------------------|----|
| 84-360 | CMU/WSP: Internship Seminar | 12 |
| 84-450 | Policy Seminar | 6 |
| 84-451 | Policy Seminar II | 6 |

Elective Seminars

Students must take 24 units from the below list of elective seminars offered in the CMU/WSP. Offerings vary by semester. (24 units):

| | | |
|--------|--|----|
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking | 6 |
| 84-333 | Power and Levers for Change in Washington, DC | 12 |
| 84-334 | The History and Practice of Economic Statecraft | 6 |
| 84-335 | US China Relations | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality | 12 |
| 84-337 | Biomedical Science Research, Policy, and Governance | 6 |
| 84-339 | Seminar in Public Policy Research | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington | 12 |
| 84-348 | Advocacy, Policy and Practice | 6 |

Foundational Course

Students select one course from the following list of courses offered at Carnegie Mellon University's Pittsburgh or Qatar campus. Students may take this course before or after participating in the CMU/WSP. (9 units):

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |

Economics Requirement

Students must complete one of the following courses. Students may take this course before or after participating in the CMU/WSP. Unlimited double counting in this category is permitted.

| | | |
|--------|--|---|
| 84-110 | Foundations of Political Economy | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-104 | Principles of Microeconomics Accelerated | 9 |

A maximum of two courses may double count between the minor in Politics and Public Policy and another major or minor.

Carnegie Mellon University Washington Semester Program

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www.cmu.edu/cmist (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>)

The Carnegie Mellon University Washington Semester Program (CMU/WSP), sponsored by the Carnegie Mellon Institute for Security and Technology (CMIST), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Full-time undergraduates from any course of study at the university may participate in the program. Students earn forty-eight units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty.

From embassies to nongovernmental organizations, think tanks to advocacy organizations, government agencies to congressional offices, and consulting firms to media outlets, Washington, DC, is the center for many political, international relations, and public policy activities. Students in the program come into direct contact with political, business, and community leaders and learn about the most pressing policy issues of the day.

Through this experiential learning program, CMU/WSP participants develop professional and networking skills, explore how coursework connects to the real world, learn to give and receive constructive feedback in the workplace and classroom, and intentionally reflect on their learning and growth. Every CMU/WSP student is paired with a Washington, DC-based alumni mentor to share career advice and tips about life in DC. CMIST also sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and policy decision making.

Students should contact the Washington Program Manager to discuss the specifics of the program and the deputy director to discuss how the CMU/WSP may fit into their curriculum. Students who participate in the CMU/WSP may qualify for a minor in Politics and Public Policy (<https://www.cmu.edu/ips/undergraduate%20degrees/minors/minor-in-politics-and-public-policy.html>).

Applications (<https://www.cmu.edu/ips/washington-dc-semester-program/application.html>) are accepted on a rolling admission basis with a final deadline of October 1, for spring semester participation, and March 1, for fall semester participation.

Curriculum

Students who are admitted to the CMU/WSP will be enrolled in the 3 unit (pass/no pass) course 84-215 Tomorrow's Professionals in the mini semester directly preceding their time in DC.

During the semester in Washington, all students enroll in the following core seminars (24 units).

Core Seminars

| | | |
|--------|-----------------------------|----|
| 84-360 | CMU/WSP: Internship Seminar | 12 |
| 84-450 | Policy Seminar | 6 |
| 84-451 | Policy Seminar II | 6 |

Students must enroll in 24 units from the below list of elective seminars. Offerings vary by semester.

Elective Seminars

| | | |
|--------|--|----|
| 84-313 | International Organizations and Law | 6 |
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking | 6 |
| 84-334 | The History and Practice of Economic Statecraft | 6 |
| 84-335 | US China Relations | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality | 12 |

| | | |
|--------|---|----|
| 84-337 | Biomedical Science Research, Policy, and Governance | 6 |
| 84-339 | Seminar in Public Policy Research | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington | 12 |
| 84-348 | Advocacy, Policy and Practice | 6 |

Faculty

AUDREY KURTH CRONIN, Trustees Professor of Security and Technology; Director - DPhil, University of Oxford; Carnegie Mellon, 2023-

IGNACIO ARANA ARAYA, Assistant Professor - PhD, University of Pittsburgh; Carnegie Mellon, 2016-

HALEIGH BARTOS, Associate Professor of the Practice - MSW, University of Pittsburgh; Carnegie Mellon, 2021-

JUSTIN CANFIL, Assistant Professor - PhD, Columbia University; Carnegie Mellon, 2023-

JOHN J. CHIN, Assistant Teaching Professor - PhD, Princeton University; Carnegie Mellon, 2016-

BARUCH FISCHHOFF, Howard Heinz University Professor in the Carnegie Mellon Institute for Security and Technology and Department of Engineering and Public Policy - PhD, The Hebrew University of Jerusalem; Carnegie Mellon, 1987-

MARK S. KAMLET, University Professor of Economics and Public Policy; Provost Emeritus - PhD, University of California, Berkeley; Carnegie Mellon, 1978-

JOSHUA SCHWARTZ, Assistant Professor - PhD, University of Pennsylvania; Carnegie Mellon, 2023-

DANIEL M. SILVERMAN, Assistant Professor - PhD, The Ohio State University; Carnegie Mellon, 2017-

Post-Doctoral Fellows

JONATHAN CERVAS, Postdoctoral Fellow - PhD, University of California, Irvine; Carnegie Mellon, 2020-

NICOLE KLIEWER, Postdoctoral Fellow - PhD, Princeton University; Carnegie Mellon, 2023-

Scholar in Residence

PATRICK CRONIN, Scholar in Residence - DPhil, University of Oxford; Carnegie Mellon, 2023-

Visiting Faculty

HANZHANG LIU, Visiting Fellow - PhD, Columbia University; Carnegie Mellon, 2023-

Lecturers

RASHALL BRACKNEY, Lecturer - PhD, Robert Morris University; Carnegie Mellon, 2018-

MATTHEW BUTKOVIC, Lecturer - Master of Professional Studies, Pennsylvania State University; Carnegie Mellon, 2015-

FRED CRAWFORD, Lecturer - JD, Georgetown University; Carnegie Mellon, 2017-

DALE CROWELL, Lecturer - MA, Catholic University of America; Carnegie Mellon, 2018-

MARCIELA DEGRACE, Lecturer - PhD, Harvard University; Carnegie Mellon, 2018-

MOLLY DUNIGAN, Senior Lecturer - PhD, Cornell University; Carnegie Mellon, 2014-

MICHELLE GRISÉ, Lecturer - PhD, Yale University, JD, University of Michigan; Carnegie Mellon, 2019-

DANIEL HANSEN, Lecturer - PhD, Michigan State University; Carnegie Mellon, 2018-

THOMAS KARAKO, Lecturer - PhD, Claremont Graduate University; Carnegie Mellon, 2015-

MATTHEW LANE, Lecturer - PhD, The Pennsylvania State University; Carnegie Mellon, 2021-

SOPHIE LE BLANC, Lecturer - PhD, University of Delaware; Carnegie Mellon, 2017-

WILLIAM M. MARCELLINO, Lecturer - PhD, Carnegie Mellon University; Carnegie Mellon, 2021-

GEOFFREY MCGOVERN, Senior Lecturer - PhD, Binghamton University, JD, Harvard University; Carnegie Mellon, 2013-

FORREST E. MORGAN, Senior Lecturer - PhD, University of Maryland; Carnegie Mellon, 2017-

BRYAN ROONEY, Lecturer - PhD, Vanderbilt University; Carnegie Mellon, 2023-

KIMBERLY SMACZNIAK, Lecturer - JD, Harvard University; Carnegie Mellon, 2017-

ANDREW J. STRAVERS, Lecturer - PhD, University of Texas, Austin; Carnegie Mellon, 2021-

MARK A. TOUKAN, Lecturer - PhD, University of Wisconsin, Madison; Carnegie Mellon, 2021-

BEVERLEY WHEELER, Lecturer - DEd, Harvard University; Carnegie Mellon, 2012-

SEAN ZEIGLER, Lecturer - PhD, Duke University; Carnegie Mellon, 2019-

Carnegie Mellon Institute for Security and Technology Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

84-104 Decision Processes in American Political Institutions

Fall: 9 units

This is an interdisciplinary introduction to the study of politics and government in the United States. It familiarizes the student with the basic structures and processes of American government, but moves beyond the purely descriptive into the realm of the analytical. The main theoretical tools are spatial models of political decision-making, and models of collective action problems. The position taken in this course is that understanding American philosophical ideas about authority, power, and freedom is as central to demystifying the U.S. form of democracy as is understanding how decision-making institutions function. Thus, on one side, this course looks at how American political thought is infused into political institutions and society. On the other side, it investigates institutional arrangements using rationalistic theories. In addition, scientific writings at the intersection of psychology and economics are used to probe the possibility of gaining explanatory leverage on U.S. politics from the perspective of behavioral decision-making theories.

84-110 Foundations of Political Economy

Spring: 9 units

Political Economics studies the interplay between economics and politics. Politicians, for example, may deviate from welfare-maximizing policies due to political pressures. Conversely, the economic and political consequences of policy decisions can shape the choices of future governments. The course will provide a broad, accessible introduction to the key issues in micro and macroeconomics, international economics, and financial markets, emphasizing those most valuable to understanding the interaction of politics and economics. The course will examine core economic concepts to illuminate how economies work, what constraints governments face, and what the welfare implications are of policy choices. From there, the course will expand to illustrate the political and ideological influences on monetary policy and central banking, the political factors shaping economic crises, the international factors influencing the implementation of domestic policies, and political influences on economic integration.

84-198 Research Training

Fall and Spring

This course is part of a set of 100-level courses offered by Dietrich College departments as independent studies for second-semester freshmen, and first- or second-semester sophomores, in the College. In general, these courses are designed to give students some real research experience through work on a faculty project or lab in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a personal and regularized meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum for students of about 9 work-hours per week. These courses are offered only as electives; i.e., they cannot be applied toward a college or major requirement, although the units do count toward graduation as elective units. Additional details (including a roster and descriptions of Research Training Courses available in any given semester) are available in the Academic Advisory Center. Restrictions: for Dietrich College students only; only for second-semester freshmen, or first- or second-semester sophomores; minimum cumulative QPA of 3.0 (at the time of registration) required for approved entry; additional prerequisites (e.g., language proficiency) may arise out of the particular demands of the research project in question.

84-200 Security War Game Simulation

Spring: 6 units

This course is a seven-week national security simulation run in coordination with Valens Global in which students will have an assigned role as a state or non-state actor and work within teams to develop policy responses to a security crisis that changes and develops over time, in response to team moves and other factors. The simulation changes each year but generally involves great power competition, directly and through non-state actor proxies. Participants will need to gain an understanding of the facts through a complex information environment that is polluted with misinformation that allows actors to engage in manipulation and deception. Students will learn how to analyze national security problems, develop and analyze options, advocate for their position, negotiate, and work within a team, as well as with other teams.

84-215 Tomorrow's Professionals

Fall and Spring: 3 units

Professionalism is the cornerstone of a healthy and productive workplace. It is a defining component of success, but it is not innate. Rather, professionalism is taught and learned. It should be practiced deliberately and developed over time and with experience. It is a specific skill set that positions individuals for success. This seminar is designed to facilitate students' deliberate thinking about professionalism, so that they can begin to practice it, building their unique brands, ensuring excellence in their internships and thus future careers. Throughout the seminar, we will discuss professional conduct, leadership, and strategies for success. We will discuss real-time workplace challenges, and problem-solve as a group to develop meaningful resolutions. Professionalism is a lifelong skill. The goal of this seminar is to provide students with the necessary tools to begin building their professional careers. Given the right tool set, it will catapult a career forward and open doors indefinitely.

84-226 International Relations

Fall: 9 units

This course introduces students to the discipline of international relations (IR) and enables students to examine the causes of war and peace, the role of international institutions and non-state actors in world politics, and the forces that shape international political economy. The course begins by surveying key concepts in world politics, such as power and international order, and reviewing the modern history of IR from colonialism to today. Students also survey a broad range of IR theories and analytical tools that help explain global politics and aid in foreign policy analysis, as well as critical, feminist, and non-western IR theory. Finally, students engage in contemporary policy debates about world politics - from the War in Ukraine to the rise of China to the future of globalization - and grapple with ethical issues related to foreign policy decision-making. Students who previously completed 84-326 Theories of International Relations are not eligible to take this course.

84-250 Writing for Political Science and Policy

Spring: 9 units

Writing and briefing are essential skills in the policy discipline. This course will equip students with the tools necessary to enter professional policy-related domains. We will use a workshop format that promotes classroom discussions, small group work and practical exercises simulating real world experiences. The workshop format is intended to emphasize communication, writing effectiveness and leadership, as well as to increase students' comfort levels with both receiving, applying, discussing and delivering constructive feedback and criticism. It is also intended to make this class fun and engaging, creating a safe and welcoming environment for students to reflect on their own work, and their colleagues'. During the course, students will write a policy memo, an op-ed, and a National Security Memo, (as well as some smaller additional writing assignments) as well as deliver multiple professional-style briefings for a variety of audiences. This is a writing intensive course, with a heavy emphasis on professional briefing and presenting. As such, students should expect to write and brief... a lot! This workshop-based model allows students to incorporate and give feedback in real time. The intent is that students will develop the skills necessary to enter future professional environments and hit the ground running. Students will work within small groups and with the professor to identify a topic Area of Interest (AOR) that will be the basis for most of their course work- allowing students to focus on an area in which they would like to develop subject matter expertise (SME), as well as one they find interesting and stimulating.

84-252 Briefing in the Policy World

Fall: 6 units

Briefing is a critical skill for the policy world as it is the most direct and formal means of communication with the policy and or decision maker. One successful brief can fast-track a career, identify you as a subject-matter-expert, and open dialogue with customers- helping build important relationships in the policy world. Briefing is a combination of presentation, flexibility and the projection of confidence- and is developed through experience. Briefing in the Policy World will equip students with the skills and confidence to excel in this realm.

84-266 Research Design for Political Science

Fall: 9 units

This course develops foundational skills in causal inference and research design in political science. It prepares students to read, interpret, and critique research effectively, and helps them begin the process of learning how to conduct original empirical research in political science. Students will learn how to formulate research questions, generate hypotheses, and design appropriate tests of those hypotheses. They will also gain exposure to different analytical methods in the field, including case studies, surveys, interviews, natural experiments, field experiments, and game theory.

84-267 Data Science for Political Science

Spring: 9 units

This course develops foundational skills in data science and quantitative analysis. The course provides students with hands-on experience in using and analyzing data to answer questions in international relations and political science. Students will learn how to wrangle, clean, or create data to test hypotheses, and how to summarize and visualize data effectively. They will also learn the fundamentals of applied bivariate and multivariate regression analysis, including model specification, estimation, and overall fit assessment, as well as the assumptions of regression analysis and their implications.

Prerequisite: 36-200

84-275 Comparative Politics

Spring: 9 units

This course is an introduction to the subfield of Political Science called Comparative Politics. In this subfield we use comparative methods to study and compare domestic politics across countries. In this course, we aim to learn about how political systems differ, discuss why they differ and explore the consequences of such variation. The course is divided into four sections. In the first part, we will examine the main theories and methods used to conduct research in the subfield, and discuss the development and consolidation of the modern state. In the second section, we will examine political regimes, including variation among democracies and nondemocracies. In the third unit, we will study some of the countries' central political institutions. We will compare political systems (presidentialism, semipresidentialism, and parliamentarism) and examine legislatures, electoral systems, and political parties. In the final segment, we will scrutinize political mobilization and conflict. We will discuss interest groups, nationalism, social movements, protests, populism, clientelism, revolutions, civil wars, terrorism, and globalization. The participation of students is central for the success of this course. You are encouraged to share your thoughts and doubts via Canvas, participate in small-group discussions each week, and participate in one group presentation that will demand you to apply the concepts and methods discussed in the course to other countries.

84-303 International Human Rights

Intermittent: 6 units

This mini-course surveys the causes of human rights violations around the world and the internal and external forces that combat them. The course begins by asking how political scientists conceptualize and measure human rights; we also review the origins and evolution of the international human rights movement and debates over whether human rights are (or should be) universal. In week 3, we survey the correlates of human rights abuses and review what progress has been made towards global forecast models of genocide, politicide, and mass killing. The core of the class in weeks 4-6 examines domestic and international forces and actors that attempt to promote human rights and assesses the efficacy of international NGOs and IGOs, international law, diplomacy and sanctions, and informal pressures of socialization and emulation. The course concludes by reviewing current human rights challenges in the United States and future of human rights globally. By the end of this course, you should come away with an appreciation for the ongoing struggle to achieve the global aspirations of the Universal Declaration of Human Rights.

84-304 In the News: Analysis of Current National Security Priorities

Spring: 6 units

This discussion-based course will examine the headlines in international relations and politics, defense, national security and homeland security. We will follow major news stories, breaking down media coverage to go deeper, conducting our own unique analysis as a group but also individually, contextualizing issues within the broader global context. Students will have the opportunity to lead discussions on breaking news stories, but also to draw upon prior past headlines which still dominate the news cycle or have wider implications for international relations. The goal of this course is to encourage students to think deliberately and deeply about current events, and to contextualize those events in the broader international relations and security context.

84-306 Latin American Politics

Spring: 9 units

The world's most unequal region is an area of contrasts. Ethnically diverse, stable and tumultuous, young and old, urban and rural, learned and illiterate, prosperous and poor, independent yet dependent. The disparities that have characterized the region since colonial times have been a permanent source of instability and the cause of numerous political and economic experiments. Social scientists have found much material to study democratic innovations, revolutions, coups, civil wars, military dictatorships, impeachments, populism, clientelism, corruption, import substitution industrialization, neoliberalism, socialism, regime changes, social movements, welfare policies, regional integration, and diversified leadership. The overarching question to be explored in this course is what forces - such as economic, social, and cultural - affect the emergence, development, collapse, reemergence, and consolidation of democracy. To understand the region's present, it is necessary to study path dependence and learn how the worldviews of dominant elites evolved over time.

Thus, the course centers in three historical periods. First, we will briefly examine Latin American history from its conquest to the end of World War II (1492-1945). The aim is to uncover the demographic and geographical setting with its economic, social, and political evolution. The second part centers on most of the Cold War period (1947-1978) and its combination of political and economic experiments. The third part covers the last forty years, from the wave of transitions to democracy to current challenges to democratic consolidation. We will also address how Latin America has integrated to globalization and how the relationship with the US and China has experienced fundamental changes since the 1990s.

84-307 Economic and Political History of Contemporary China

Intermittent: 9 units

Global politics is increasingly being shaped by the arrival of China as an economic powerhouse, which is increasingly being viewed as a challenger to the Western model of governance and has been posited as an anti-western economic blueprint for development. To understand China and its role in global affairs, this course examines the economic and political history of China over the last century with an emphasis on the post-WWII period. Focusing on China's evolution over this time will introduce students to compelling illustrations of theories of economic development and the politics of economic reform, the intersection of political governance and economic outcomes, how authoritarian regimes function and make decisions, and how politics can lead to humanitarian catastrophes such as the Great Leap Forward and Tiananmen Square. The course will also cover important aspects of Chinese foreign policy and how it is evolving - from the years of Mao Zedong, to Deng Xiaoping and currently under Xi Jinping. This course will also enable a more mature understanding of socialism as an economic ideology, how it contrasts with a purely market-based approach, and how modern China fits within this framework.

84-310 International Political Economy

Fall: 9 units

This course explores how political institutions, processes, and actors influence economic interactions both domestically and internationally. During the semester, we will address two key questions: 1) how do governments collaborate to regulate, and stabilize, the trans-boundary flow of capital, goods, and services?; 2) what are the distributional and political consequences of the current world economic order? In exploring these questions from diverse theoretical lenses, we will discuss topics ranging from monetary and exchange rate policies, international trade, and global integration of production to the role of multinational corporations, social movements and civil society organizations, as well as institutions for corporate social responsibility, in the global economy. By the end of the course, students will be prepared to compare and contrast the theoretical propositions, and policy recommendations, of rival schools of thought. Prerequisites: 88-220 or 12-421 or 73-102 or 73-100 or 84-110

84-312 Terrorism in Sub-Saharan Africa

Intermittent: 6 units

The spread and growth of terrorism on the continent of Africa has increased substantially over the last decade; this mini is an introduction to the major terrorism groups that operate in sub-Saharan Africa. Throughout the course, we will examine the nexus of the terrorist threat in sub-Saharan Africa, and subsequent responses from governments, multinational organizations and foreign actors. It is intended to acquaint students with the dynamics of terrorism and counterterrorism efforts in sub-Saharan Africa, and by doing so establish a solid foundation upon which further expertise can be built.

84-313 International Organizations and Law

Fall: 6 units

This course provides students with a comprehensive overview of the role and function of international organizations and international law in global affairs. In this course, we will consider the historical development of the international legal system and theories and sources of international law. We will examine the dynamics of key international organizations within the United Nations system, the emergence of regional organizations and their role in global governance, and the relationship between international law and domestic law. Throughout the course, students will be asked to analyze current events through the lens of international law. Students will learn to read and analyze primary legal sources and gain familiarity with current research in the field. By the end of the course, students should be able to assess the record of international institutions in promoting international security, facilitating and regulating the use of emerging technologies, influencing the conduct of war, protecting human rights, and addressing global environmental concerns.

84-315 Political Economy of International Migration

Spring: 9 units

International migration - the movement of people across national borders - is a defining political and economic phenomenon of our time. Rising social and political conflict over migration - not just in advanced democracies but also in the Global South - means that understanding the causes and consequences of international migration is more important than ever. Using analytic frameworks and real-world evidence from political science, economics, and related fields, this course gives students a full understanding of the political economy of international migration. By the end of the course, students will be able to answer questions like: why do people migrate? How do they choose where to go? How do migrants re-engage with their homelands? Students will also explore migration's political and economic consequences, like backlash against immigration and "brain drain" (or gain). In the process, the course will grapple with how countries set their immigration policies and whether migration benefits or harms natives. Students will use real-world quantitative data to uncover their own insights on the drivers and impacts of international migration.

84-316 Political Economy of Transatlantic Partnership

Fall: 9 units

The changing international world order due to China's rise as a global economic superpower and the rise of authoritarianism and populism in developed economies have created new challenges and opportunities in the transatlantic community. This course examines the key economic issues in current transatlantic relations. Our focus will be on the economic cooperation and tensions between the two largest economies and the largest trade and investment partners in the 21st century, the United States and the European Union. We will identify the recent disruptive global economic events, including the financial crises, Brexit, China's accession to the World Trade Organization, regulatory affairs, COVID-19, and supply chain problems, and discuss the governance and institutional structures the US and the EU have put in place to overcome these challenges. Additionally, we will analyze the populist and nationalist challenges to the liberal democracy and how domestic political forces have resulted in environmental, economic, and human rights crises on both sides of the Atlantic, as seen in recent tariff wars, failed international agreements, and the refugee crisis. Students will leave the course with a stronger appreciation for the US and the EU's commitment to advance a rules-based international order and strategic cooperation despite distinct approaches to economic policy.

84-317 Defense Resourcing: From Strategy to Execution

Intermittent: 6 units

A must take class if you have any plans of becoming a civil servant, defense contractor, or work for/own a company that receives defense funding. The Planning, Programming, Budgeting, and Execution (PPBE) process translates the national security strategy, national defense strategy, and national military strategy into trained and ready forces for combatant commands and #8212; units of personnel and equipment that mobilize, deploy, conduct and sustain operations, redeploy, and demobilize. Consisting of four distinct but overlapping phases, the annual process serves as the framework for the Department of Defense civilian and military leaders to decide which programs and force management requirements to fund based on strategic objectives. Current Secretary of Defense Lloyd James Austin III has requested a 2023 budget of \$773 billion in order to 1) maintain a combat credible force to defend the homeland; 2) marshal America's next generation of technology; 3) effectively maintain readiness, and 4) take care of the men, women and family members of the U.S. military. This class will examine the PPBE process by discussing this budget along with the strategies, decisions, and politics that created it. Students will gain a general grasp of the PPBE process and learn to think critically when developing and/or interpreting strategies.

84-318 Politics of Developing Nations

Spring: 9 units

Be it on our feet, in our grocery bags or in the news, our daily lives connect us to people in the developing world. Despite such an intricate relationship, we tend to know very little about developing nations and their challenges beyond a common stereotype of poverty. What are developing nations? What is their place in the world? What challenges do those nations and their populations face? In this class, we will strive to answer those questions through readings of political science and political economy scholarship and in-class activities and discussions. We will explore the socio-economic and political issues that developing nations face and take special care to practice perspective taking (i.e. we will put ourselves in specific nations' shoes and consider situations from their point of view). We will adopt various lenses (e.g. post colonialism, liberalism, feminism) throughout the semester to inform our understanding of the various positions taken by global actors. By addressing the unequal power balance between developed and developing nations as well as among developing nations, we will enrich our world view and understanding of major global issues, such as development. We will practice those skills in class through discussions and activities (you should expect very little lecturing) and outside of class through guided readings. Your learning in the course will be assessed through various writing assignments (take home exams, a final paper, weekly responses) where you will practice composing arguments based on evidence.

84-319 Civil-Military Relations

Spring: 9 units

Why do militaries (people with guns) ever obey civilians (people without guns)? Can we have a military strong enough to protect civilians, yet not so strong as to ignore or subvert civilian authority? What is the dividing line between civilian and military spheres of activity? How much influence should civilians have on activities within the military sphere, and how much influence should the military have in the civilian sphere? How does all of this affect a state's ability to both protect itself and project power globally? Examining the theory and practice of civil-military relations in the U.S. and the world, this course explores issues related to civilian control of the military and military professionalism, including coups d'etat, military disobedience, the impact of an all-volunteer vs. conscripted force on both civilian and military decisions, public-private partnerships in the military sphere, the role of military privatization in civil-military relations, and the role of servicemembers in the political life of the community. Relying on the influential texts of Lasswell, Huntington, Feaver, and Finer, the first half of the course aims to elucidate the theory behind basic tensions between the military and civilians. The second half of the course focuses on how theory translates into practice, with a particular focus on case studies of civil-military relations in the U.S. democratic system.

84-322 Nonviolent Conflict and Revolution

Spring: 9 units

How can everyday people promote justice, equality, and democracy? Throughout history, many have looked to armed struggle and revolutionary violence. But over the course of the last century, nonviolent "people power" movements and #8212; from Gandhi's salt march to the Arab Spring to Black Lives Matter and #8212; have been forces for social and political change. What are the causes, strategies, tactics, dynamics, and consequences of nonviolent conflict, and how do these differ from violent or armed conflict? When and how do unarmed "people power" campaigns topple repressive authoritarian regimes? This course addresses these questions, and, in the process, engages contending theories of power, revolution, and insurgency. The course introduces students to key concepts, theories, strategies, and historical patterns of nonviolent conflict. The class probes the success and failure of nonviolence by analyzing landmark unarmed revolutions.

84-323 War and Peace in the Contemporary Middle East

Spring: 9 units

This course examines the drivers and dynamics of war and peace in the contemporary Middle East. It is structured around a series of key debates about different facets of conflict and violence in the region, such as the causes of rebellion, the reasons resistance groups use terrorism, and the factors that facilitate peace. We will delve into competing arguments about each of these issues, applying the ideas to cases around the region. We will also examine broader regional conflicts like the Arab-Israeli dispute and Sunni-Shia confrontation. We will use a mixture of research articles and books as well as more diverse materials such as war reporting, films, and memoirs in order to create a holistic understanding of these issues.

84-324 The Future of Democracy

Intermittent: 9 units

After the Cold War, Francis Fukuyama famously argued that humanity had reached the "end of history" insofar as liberal democracy had become the last viable form of government. Yet today, illiberal democracies and dictatorships persist, the world has witnessed the return of authoritarian great powers led by China and Russia, and populist movements challenge liberal democracies around the world. What is the future of democracy around the world, and how can we know? This course surveys the causes of historical rise (and fall) of democracy, the methods and pitfalls of democracy promotion, and a variety of challenges to democracy and #8212; such as nationalism, polarization, and misinformation. By the end, students will be expected to write an intelligence memo and give an oral presentation on the future of democracy in a particular region or country.

84-325 Contemporary American Foreign Policy

Spring: 9 units

This course provides a survey of American foreign policy since World War I as a means of explaining why American foreign policy looks the way it does today. We will cover topics such as America's perennial battles between isolationism and internationalism, the creation of the US-led world order after 1945, the containment of communism, and anti-terrorism after 9/11. We will cover enduring and global issues like climate change, nuclear non-proliferation, humanitarian intervention, and international economic policy, as well. Further, a main focus of the course is how foreign policy is made - the role each branch of government plays in foreign policy making, the impact of domestic politics and public opinion, and how other countries receive and react to American foreign policy. The course will use both history and data analysis to understand how foreign policy works, how it is made, and its effect both at home and abroad. A good grasp of the 20th century American and world history, and some familiarity with international relations theory are not requirements but will prove helpful. By the end of the semester, students should have acquired a broad understanding of the most important foreign policy events of the last century and have the tools to analyze foreign policy decision-making.

84-327 Repression and Control in Dictatorships

Fall: 9 units

How do dictatorships exert physical and social control over their populations through state coercion? What tools and institutions do they use, and what makes dictatorships' use of coercion distinct from that of democracies? Why is so much of the population complicit in or about, the human rights abuses which result from these control efforts? This course, drawing on research across social science and history, answers these questions by analyzing the institutions, processes, and consequences of governments' mechanisms of physical and social control. Among other topics, we will examine the origins of state coercion, the structure and organization of state coercion, and the cooperation of civilians and other social actors with coercion. Beyond physical-legal coercion, we will evaluate 'softer' forms of social control such as propaganda, censorship social pressure, and 21st-century digital strategies of information manipulation. We will also consider the imprint of physical and social control on the population's beliefs and behavior, both during the time they are subjected to coercion and the period following its end. Students will engage with these questions through (1) in-depth class discussions based on insights from historical and present-day dictatorships and (2) conducting original research and analysis of evidence.

84-328 Military Strategy and Doctrine

Fall: 9 units

This course will survey how the causes, conduct, and termination of warfare have changed over time. While the focus of the course is primarily on major warfare between states, we will also cover the use of military power in civil wars, insurgencies, and proxy wars. The first part of the course addresses why wars occur and what leaders hope to achieve using military power. We will cover the merits and limitations of different explanations for why war occurs and different ethical issues in the use of force, including just war theory and protection of civilians. The second part of the course addresses the sources of warfighting effectiveness, war outcomes, and war termination and will cover a range of material and non-material factors. The final section of the course will cover how recent military, technological, social, and political changes influence what can be achieved through military power and implications for military strategy and doctrine. By the end of the course, students will have general grasp of the major analytic approaches to understanding the occurrence and dynamics of war and will have the tools to think critically about the use of military force.

84-329 Asian Strategies

Intermittent: 6 units

What are the strategies of leading Asian countries? How do their governments intend to pursue their economic, political, and military goals in the years ahead? What role will technology and information play in advancing their strategic objectives? These questions are the heart of this mini-course, focusing on some of the most problematic and promising regional states: North Korea, South Korea, China, Japan, and India. While all these actors have a rich history, they were born anew within five years after 1945, with the conclusion of the Second World War, the division of the Korean peninsula, the partition and independence of India, and the founding of the People's Republic of China. The course will culminate in a discussion of strategic convergences and the divergences, as well as the implications of national strategies for regional and global peace and stability.

84-330 The Shading of Democracy: The Influence of Race on American Politics

Intermittent: 6 units

This course will explore intersections of race, political influence and the shaping of America's democracy. Discourse will focus on racial and ethnicity-related policies, practices and processes designed to influence democratic outcomes. Students will examine complex, and often pivotal occurrences that have transformed the political landscape through the works of Richard Rorty, *Achieving Our Country: Leftist Thought in Twentieth-Century America*; Michelle Alexander, *The New Jim Crow: Mass Incarceration in the Age of Colorblindness*; and, Steve Phillips, *Brown Is the New White: How the Demographic Revolution Has Created a New American Majority*.

84-331 Money, Media, and the Power of Data in Decisionmaking

Intermittent: 6 units

This course focuses on the impact of three critical influences on policy and decisionmaking in Washington D.C.: money, in the form of political campaign dollars in particular; media, from national to local; and data that can define the policy problem and solution. The course will dive into each topic through a series of case studies of policies whose successful adoption and implementation hinged upon money, media or data. Students will come away from the course with the background and context to critically consider tough questions about the right role of these powerful influences on national policy. (Is the media "broken"? ; What is the prospect for moderating the impact of money on policy? ; Is the influence of data and facts on the wane in a hyper partisan political context?)

84-333 Power and Levers for Change in Washington, DC

Intermittent: 12 units

Political and policy change often appears to sweep in at the direction of high-profile, centralized decision makers. The path to change is in truth a longer tale, driven by a diversity of actors and influencers. This course aims to more fully map out the diversity of levers that drive change in federal policymaking and implementation, examining key influences such as Congress, money, media, social movements, rhetoric and data. The course aims to give students a fuller picture of how their own particular strengths and interests are valuable to creating change, through seminar dialogue, guest speakers, and reflections on students' internship organizational structures.

84-334 The History and Practice of Economic Statecraft

Intermittent: 6 units

The use of economic tools in a world of dense international economic networks to coerce other governments to achieve foreign policy aims is central to understanding the world we see and in augmenting our understanding of the wisdom of various policy options. Economic statecraft impacts target and sender governments, generates spillover effects on external countries, the domestic economy and social stability, and business and NGO perceptions of risk and the viability of participating in foreign countries. This course will first deeply explore the history of economic statecraft and concepts underpinning the strategic calculations regarding its use. It will scrutinize the most evocative form of policy - economic sanctions - in addition to broader frameworks of statecraft which utilize multilateral forums which are the "carrots" of international economic policy. It will also educate students on the state of the literature regarding sanctions' efficacy, and understanding what features of the economy render target states most vulnerable to coercion. In this way we will contextualize claims that Russia "sanction-proofed" its economy prior to its invasion of Ukraine in 2022 and gain deeper insight into the unprecedented sanctions which have been imposed as a result. The course will also discuss the Iranian case, assess Chinese economic statecraft, and conjecture about how economic statecraft fits within the broader context of an emerging US-China rivalry.

84-335 US China Relations

Intermittent: 6 units

It is commonly argued that the US-China relationship is the single most important relationship that will define global affairs for the remainder of the 21st century. How this relationship is managed and the decisions made by each side will have dramatic implications for the political and economic stability of the world. Some argue that China's rise portends the inevitability of great power conflict, with little hope for any meaningful cooperation and the substantial risk of military confrontation. Others suggest that while US-China relations are increasingly adversarial, the inherent threats are containable and seek what is termed "competitive coexistence". Most, however, agree that the era of engagement with the hope for deepening cooperation is now past. This course will chart the evolution of US-China relations, from the founding generation of the United States and the end of the Qing dynasty, through the Chinese civil war and the rise of the CCP, to the warming of relations under US President Nixon and China's subsequent Reform and Opening period - ultimately setting the stage for an understanding of the current US-China landscape. Throughout this history, we will briefly touch on theories of international relations to help frame our thinking for these periods of history, discuss how to interpret current challenges to this relationship (and whether democratic institutions are an advantage or disadvantage in this competitive environment), and project what may or may not be attainable goals for the decades to come.

84-336 Implementing Public Policy: From Good Idea To Reality

Spring: 12 units

Good public policy doesn't just "happen." Rather, successful policy is the result of thorough research, careful drafting, and successful navigation within the government or non-government organization whose leadership may ultimately promulgate it. The course begins with a brief review of government and organizational behavior in a bureaucracy, and the identification of a federal agency's current policy system as a framework to which we will turn throughout the term. Study then turns to an overview of legal research skills. Though usually the province of law students and attorneys, such skills will enable students to know when policy may be crafted "from scratch" and #8212; or where, when, and how policy must conform to larger governing legal or regulatory structures. Students will then consider a particular sub-specie of public policy, administrative law, which addresses the special circumstance of regulatory agencies and the statutory regimes that create and govern them. The course culminates with students developing and "staffing" a notional policy, modeled on the federal agency policy system studied throughout the term. This course may benefit a range of audiences: students considering government and related policy careers; future business leaders who must set standards for business practices, employee behavior, or operations within the confines of governmental regulations; prospective paralegals and attorneys; or anyone interested in exploring "what the rules are" and why.

84-337 Biomedical Science Research, Policy, and Governance

Intermittent: 6 units

This course is designed to explore how the biomedical sciences intersect with policy and governance on a national and international scale. The course will explore how the US funds biomedical science, how Congress and government agencies implement science policies, and the policy implications of new scientific fields using topics such as emerging infectious disease, genomics, stem cell research, etc. We will also use the SARS-CoV-2 pandemic as an example to explore topics related to science policy including funding, FDA regulation, and international cooperation. By the end of the course, the students will be able to understand the process of policy implementation in the US government and consider the effects of policy on biomedical science.

84-339 Seminar in Public Policy Research

Intermittent: 12 units

Public policy has high stakes. The taxes we pay, our access to medical care, the quality and composition of the military- all of these are the direct result of US public policy. Furthermore, public policy often touches on highly contested issues such as private gun ownership or single payer health care. Public policy research then is important, helping inform critical political decisions with evidence-based analysis. This seminar will give students an overview of public policy research concepts, terms, and actors. This will be followed by a case study unit on exemplars of public policy research: the opening of all military occupations to women, and the passage the Affordable Care Act. A third unit will focus on the increasing role of scalable analytics and large datasets. In this unit students will gain an overview of scalable methods (including machine learning applications), the potential of "big data" to transform policy research, but the problems and pitfalls associated with a more algorithmic approach to public policy. These three units will build towards a final research project where students propose their own policy initiative.

84-340 Making Change: How Organized Interests Work in Washington

Fall: 12 units

American politics has many elements and founding principles. Among them is the right of individuals- alone or in groups- to assemble and petition the government in pursuit of their interests and beliefs. This class will highlight the intersection between pressure groups, politics, and policy in Washington, DC. More specifically -based in the political science and other academic literature- the class will examine how organized interests engage and try to influence elected and public officials as they make decisions and take actions related to the nation's political and policy agenda. The class will also interact with Washington-based advocacy and lobbying organizations to see how those ideas are applied in real life scenarios.

84-348 Advocacy, Policy and Practice

Intermittent: 6 units

This course examines the role that advocacy and advocacy organizations play at all stages of the policymaking and implementation process, from grassroots to professional advocacy organizations, public facing communications initiatives to internal policy-focused actions. Part of the course will focus on the history of advocacy in policy making, and case studies will be used to explore the players, outcomes, and influences of advocates when designing and implementing policy.

84-352 Representation and Voting Rights

Spring: 9 units

What does it mean to be represented? Who is represented, who is not? What is the nature of that representation? In practice, does representation result in policy congruence? In this course, we will explore the concept of representation, what it means in theory, and how it works in practice. We will investigate the theoretical underpinnings of representation from a democratic norms' perspective, the legal and constitutional nature of U.S. institutions, and evaluate empirically how well represented the public is. The class will have a central theme of how race and racial attitudes affect representation. Voting rights, the Voting Rights Act, and subsequent court cases will be highlighted. In the United States, legislative elections are held in single-member districts, which require the drawing of district boundaries every decade. Several weeks of the course will be devoted to understanding this process. The course will culminate with a final project in which we will draw electoral maps that could act as alternatives or remedies to maps enacted this decade.

84-354 The American Experiment: Unravelling the US Electoral System

Spring: 6 units

In 2022, U.S. Supreme Court Justice Stephen Breyer noted that Americans are participating in a democratic experiment that Thomas Jefferson launched with the Declaration of Independence. The same unique and improbable system outlined by the Framers of the Constitution continues to shape modern politics and guide how we select our political leaders - both positively and negatively. This course will explore the intricacies of the U.S. electoral system and trace its historical evolution. Through this process, students will gain a detailed understanding of the foundations of our current electoral system and the challenges it faces. Students will also be asked to engage thoughtfully with the systems strengths and weaknesses and consider potential reforms. Altogether, this course invites students to unravel the complexities of elections and appreciate their significance in the broader democratic experiment.

84-360 CMU/WSP: Internship Seminar

Fall and Spring: 12 units

The internship is the experiential "core" of the Washington Semester Program. Students intern three days per week, for approximately 24-25 hours, in offices from Capitol Hill to the White House and including opportunities in cabinet agencies, nonprofit institutions, museums, advocacy groups, policy think tanks, cultural institutions, and news organizations. Through the internship, students gain professional experience and make long-lasting professional and personal contacts. In addition, students meet once a week with the CMU internship faculty for a 2-hour seminar to report and reflect on their internship experiences, and address pressing current issues from the perspective of their internship organization. In addition, the weekly seminar typically includes 1-2 CMU alumni from the Washington, DC, area. Their personal and professional experiences become part of the seminar conversation, and they make themselves available to students as ongoing sources of information and advice. THIS COURSE IS RESTRICTED TO STUDENTS PARTICIPATING IN THE CARNEGIE MELLON UNIVERSITY WASHINGTON SEMESTER PROGRAM (CMU/WSP) ONLY.

84-362 Diplomacy and Statecraft

Fall: 9 units

Diplomacy and statecraft are the driving forces behind foreign policy and international politics. In the first part of the course, students are introduced to the concepts, theories, and history of diplomacy. Students survey examine key cases and statesmen and women in great power politics from the Congress of Vienna to the present. Finally, the class surveys contemporary diplomatic challenges related to international security, major power relations with Russia and China, human rights and democracy promotion, and non-traditional transnational threats (human trafficking, global climate change). Both in the classroom and in writing, students are encouraged to think, act, and write like diplomats and to appreciate diplomacy as a vocation. Throughout the course, students build skills in foreign policy memo writing, participate in diplomatic role-playing simulations, build cultural intelligence, and connect diplomatic trend lines with today's international headlines.

84-365 The Politics of Fake News and Misinformation

Spring: 9 units

This course analyzes the drivers and dynamics of fake news and misinformation in social and political life. From conspiracy theories about COVID and climate change to misinformation about political violence and conflict, how can we characterize fake news and misinformation and why does it often spread so widely? What are the factors that explain why individuals accept or reject it? And what are its consequences for our political behavior? In this course, we will explore these and other questions on fake news and misinformation, drawing on the fast-growing body of research on the topic. In particular, we will first focus on defining and characterizing the problem of fake news and misinformation, and then we will examine its production, consumption, and consequences. As the final assignment in the course, students will write an original research paper applying ideas from class to an example of fake news or misinformation of interest to them.

84-369 Decision Science for International Relations

Fall: 9 units

Decision Science looks at choices from three interrelated perspectives: analysis, characterizing decision makers' options, in terms of expected effects on outcomes that they value; description, characterizing decision makers' beliefs and preferences; and interventions, helping decision makers to choose among the options available to them or create better ones. The course integrates foundational research in Decision Science with applications to international relations and politics. Prerequisites: 19-250 or 36-200 or 36-201

84-370 Nuclear Security & Arms Control

Spring: 9 units

This course introduces students to the importance and challenges of implementing the safeguards surrounding nuclear energy and arms control. Students will learn the challenges of nuclear and conventional weapons proliferation, current treaties and export control organizations and assess their effectiveness, and evaluate policy challenges related to emerging weapons technologies, particularly drones and AI.

84-372 Space and National Security

Spring: 9 units

Space systems contribute a great deal to America's security, prosperity, and quality of life. This course examines how space-based services provide critical support to military and intelligence operations and contribute to national security more broadly. The course is designed to investigate several interrelated themes, weaving together relevant aspects of technology, strategy, and policy. The material is approached from both functional and historical perspectives, beginning with the basics of military and intelligence space operations and ending with an examination of the space- and cyber-related technical, strategic, and political challenges facing the nation today and in the foreseeable future.

84-373 Emerging Technologies and International Law

Spring: 9 units

This course is a study on the complicated relationship between politics, technology, and international law. While the efficacy of international law is often debated, countries generally depend on it to help regularize the world. Today, however, a proliferation of new technologies - including drones and autonomous weapons systems, cyber threats, hypersonics, space privatization, and more - may profoundly disrupt that world. By surveying historical, contemporary, and horizon technology cases, we will discuss how countries sometimes design technologies to exploit legal loopholes, at other times attempt to engineer against creativity by "future-proofing" or adapting international law to emergent threats, and how equilibrium is restored when these efforts fail. Notwithstanding the relevance of international law for many domains of social activity, the focus of this course will be on the maintenance of international/human security, including arms control, the laws of war, and public international law governing security practices.

84-374 Technology, Weapons, and International Conflict

Fall: 9 units

"Advancements" in military technology over time have enabled countries to kill quickly, with pinpoint precision, and on a massive scale from thousands of miles away. Today, emerging technologies also empower state and non-state actors to use lethal force via remote control and may even allow machines to kill autonomously. While once the purview of science fiction, lethal autonomous weapons systems and #8212;sometimes referred to as killer robots and #8212;are becoming a reality. This course will trace developments in military technology from the gunpowder revolution in the 15th century and the nuclear revolution in the 20th century to emerging technologies like drones and artificial intelligence in the 21st century. Along the way we will assess the development, spread, effectiveness, and morality of these technologies and address critical questions for scholarship and policy. Are nuclear weapons a net positive or negative for international security, and will they ever be employed again or is there a "taboo" against their use? Do drone strikes increase or decrease terrorism, and what impact do remotely controlled systems have on conflict between states? Does military technology determine victory and defeat on the battlefield, and how have technologically inferior actors like the Boer, Viet Cong, Mujahideen, and Taliban managed to beat superpowers such as the United Kingdom, Soviet Union, and United States? Why are some countries able to successfully innovate whereas others fail? Do states always pursue military technologies to improve their security, or does the desire for status and prestige sometimes impact the kinds of weapons states want? Could the use of lethal autonomous weapons ever be considered ethical? These are just a handful of the questions we will explore in this class.

84-380 US Grand Strategy

Fall: 9 units

What role should the United States play in the world? Should the U.S. solely protect its own borders or advance democracy, promote human rights, and contain aggressive countries? These are questions that Americans have wrestled with throughout modern U.S. history. In this class, students will learn about those arguments and engage in debate over both the goals of U.S. foreign policy and the means of achieving them. This course will situate current events in the historical context of grand strategy during and after the Cold War, as well as a wider understanding of how countries determine their goals and seek to pursue them through a combination of diplomatic, economic, military, and political means. Students will explore the connection between domestic and foreign affairs and how all these issues relate to current U.S. strategy toward a rising China, an assertive Russia, and so-called "rogue states" like Iran and North Korea. Students should emerge from the class with a better understanding of U.S. grand strategy but also with a greater ability to formulate and communicate their own views on U.S. strategy toward the rest of the world.

84-383 Cyber Policy as National Policy

Spring: 6 units

The decisions nations make in cyberspace have profound implications for both prosperity and sovereignty. The internet is a digital thread tying together peoples. The nature of our participation in this ecosystem is determined by policy makers. Cyber policy mirrors the political ethos of governments. Some nations choose to use cyber as a tool of control and repression, others construct cyber policies as key enablers of innovation and the free exchange of ideas. The translation of traditional policy objectives into a direction for cyber is often problematic. The perpetually liminal state of conflict in cyberspace adds another set of challenges for policy makers. In this course we will explore national cyber policies. We will compare approaches and explore the role of culture. In our analysis we will enumerate the attributes of effective national cyber policy and conduct postmortems on failed policies. We will examine the ethical questions faced by cyber policy makers. Every citizen has a role in cyber policy. This course is intended to prepare future policy makers and create informed citizens.

84-386 The Privatization of Force

Fall: 9 units

This course considers different forms of privatized force and security over time and across various strategic contexts, from historical mercenarism up to modern-day private military and security contractors. While going through the historical and modern material chronologically, the course considers the various issues that arise with each form of privatized force, including questions that arise regarding the state's monopoly on violence, legal and humanitarian issues, and civil-military relations. These range from theoretical concerns regarding modern definitions of the state, to practical operational-level concerns pertaining to field coordination issues between the military and private contractors in modern conflicts.

84-387 Remote Systems and the Cyber Domain in Conflict

Spring: 9 units

This course analyzes the impact of remote systems and the cyber domain on national security. We will study the development of these technologies, how and why they have been used by state and non-state actors in conflict, their impact on the battlefield, and potential future developments. Some of the questions we will explore in this class include: Are drones revolutionizing warfare between states? Does the use of drones by state actors increase or decrease terrorism, and how are terrorist groups utilizing drones to achieve their goals? How does support for retaliation and escalation in response to cyber attacks differ from more traditional, kinetic attacks? How have remote systems and cyber capabilities been utilized in the Russia-Ukraine War?

84-388 Concepts of War and Cyber War

Fall: 6 units

This course examines traditional theories, concepts, and practices in international relations and warfare- conventional, unconventional, and modern- and relates them to the emerging dynamics of cyber war. The principal concepts examined in this course reflect, have shaped, and continue to shape state and non-state actor behaviors and their calculations of how to prepare for and prosecute warfare. These include, among others, conventional and nuclear deterrence, offense-defense dynamics, first strike capabilities, and irregular warfare. The course will focus on theory but will leverage history, military doctrine, and cases to highlight the challenges of integrating cyber war into defense planning and practice. Students will be challenged to consider how the introduction of cyberspace as a warfighting domain- in addition to land, maritime, air, and space- affects the ways that scholars and practitioners- operating with force structures and strategic, operational, and tactical concepts that are decades, if not centuries old- conceive of and practice warfare in the 21st Century. The principal objective of this course is to introduce students to cyber war within the context of traditional, and emerging, concepts of armed and unarmed warfare. This course will focus on two core areas: 1) a discussion of traditional concepts of warfare in the physical domains; and, 2) a discussion of cyber war and its intersection with these traditional concepts.

84-389 Terrorism and Insurgency

Spring: 9 units

There are many forms of political violence but not all are created equal. Some, like terrorism, are a tactic while others, like insurgency, are a strategy. How important is it to define terrorism and insurgency? What causes insurgencies, and what determines the choice of terrorism as a tactic within insurgencies? This course will go into depth to analyze the various manifestations of terrorism and insurgency. The course will cover the historical evolution of terrorism and insurgency as well as recent trends. The course will also focus on groups, methods, ideologies, and organizational structures, and will address the effectiveness of different policies over time at managing insurgency and terrorism, and the role that these policies play in U.S. strategy.

84-390 Social Media, Technology, and Conflict

Spring: 9 units

This course will examine the role that social media and technology have had on conflict at multiple levels, both between and within nations. Interconnectedness has expanded dramatically and continues to expand, allowing the formerly disconnected individuals with shared political views, states and diaspora populations to be intimately connected. The Arab Spring uprisings were significantly influenced by the use of cell phones, social media, and text-messaging as organizing tools. Insurgent groups like the Islamic States harnessed the power of social media and emerging technologies, and now extremist groups in the US and Europe are using Twitter, YouTube, Telegram and other social media platforms to their advantage. Information war is a critical factor in Russia's invasion of Ukraine, as both sides work to support/exploit kinetic warfare. Social media is used both to recruit for and fund violent extremism, while the internet has become a channel for radicalizing individuals into violent ideologies. Loss of trust in media and institutions, and the proliferation of mis/disinformation, conspiracy theories, and malign information operations over social media has introduced a new dimensions to conflict and relations between individuals, small groups, non-state actors, and nation-states.

84-393 Legislative Decision Making: US Congress

Spring: 9 units

This course analyzes decision-making by the United States Congress. The course examines legislative behavior by focusing on the way Congress is organized (institutional and constitutional structure) and the ways legislators, voters, and various other parties interact (strategic constraints). Students will both learn the legislative process and explore the influence of norms, rules, expectations, incentives and, perhaps most important of all, the power of the electorate in influencing legislative outcomes and policy. Elections, voting decisions, committee assignments, political party power, and intra-branch relations across the Federal government are some of the topics into which we will delve. This course does not require any prior knowledge of the U.S. Congress, and there are no prerequisites for the course.

84-402 Judicial Politics and Behavior

Spring: 9 units

This course is a survey of research and insight into one of the most unique American government institutions: the judiciary. Rather than exclusively reading case law (as one would do in a Constitutional Law class), this course examines court structure, rules of law and, most importantly, judges as actors within an institutional setting. We will focus on how rules, norms, and expectations guide the decisions, actions, and range of options available to judges. Here we will study the nature of judicial decision-making and its antecedents, the organization of the judicial branch and its implications for behavior, and the strategic interactions both within courts and between the courts and the more "political" branches of government. The course will look at state and federal courts within the United States, supplemented with examples from international jurisdictions. Material from law, history, economics, political science, sociology, and psychology will be introduced throughout the semester. Although some of the literature uses empirical and/or game theoretical models, students are not expected to have mastered these tools prior to taking the course.

84-405 The Future of Warfare

Fall: 9 units

Warfare is constantly evolving. In the contemporary conflict environment, the prospect of large-scale conflict between great powers is converging rapidly with proxy conflicts and threats typically posed by irregular actors and tactics. Great power competition between the United States, Russia, and China is increasingly playing out on the global strategic stage, while hybrid actors and proxy groups continue to wage war in an asymmetric and irregular manner that relies on ambiguity, strategic surprise, and deception. These activities often occur within the so-called "gray zone," an area of neither declared nor undeclared hostilities where U.S. adversaries are gradually allocating resources. This course will examine and historically contextualize various "new" trends in warfare, including the weaponization of AI technologies, increasingly sophisticated cyber and information warfare operations, the development of violent non-state actors with conventional military capabilities, and state support of mercenary forces to achieve strategic gains without attribution.

84-421 Advanced Topics in American Politics

Fall: 9 units

This upper-level course examines prominent classical and contemporary works in the two major subfields in American politics, political institutions and political behavior. This means the seminar will address topics such as Congress, presidency, bureaucracy, and courts, but also public opinion, elections, campaigns, political parties, and the importance of geography, wealth, ethnicity, gender, and religion in politics. There will be an emphasis on analyzing and appraising the theory, methodology, and contributions of the selected readings, and on discussing their complementarity. Intensive discussions and written essays are key components of the course. Prerequisite: 84-104

84-440 Collaborative Research in Political Science

Spring

Are you interested in joining an inter-disciplinary, collaborative research team that could eventually lead to publishing a co-authored article in political science? This course invites interested students to join as active participants in one of several ongoing research projects by a faculty member in the Institute of Politics and Strategy. Students will be grouped into small teams of co-authors based on interest and skills. Some students may take the lead with data collection and cleaning, others with writing a literature review or case studies, others still with analyzing and visualizing data. The goal will be to draft a co-authored paper by the end of the semester that may be presented at a conference and, ideally, published in a journal. Students from all backgrounds are welcome, especially those with an interest in politics, history, international relations, or social science applications of statistics, data science, and/or machine learning. SPRING 2023 TOPIC: Technologies of rebellion and the politics of coups, self-coups, assassinations, mass protest, and/or armed insurgency.

84-450 Policy Seminar

Fall and Spring: 6 units

The Policy Seminar course takes a critical look at decision making in domestic politics and US foreign policy. It does so through weekly roundtable discussions with a diverse set of thought leaders. Based on intellectually significant essays that students are expected to read in advance of each class, these discussions give students an opportunity to ask probing questions about the three branches of the US government, media, embassies, advocacy groups, international organizations, and nongovernmental organizations. This course seeks to help students understand the responsibilities and activities that leaders and decision makers carry out on behalf of their organizations. Students are instructed in how to confidently and respectfully ask critical questions of those shaping policy. The term "roundtabling" is used to describe submitting an issue for critical discussion among relevant stakeholders. Knowing how to direct a roundtable is a significant element in the professional development of anyone interested in taking part in the policy arena, and this course helps students hone this important skill. In requiring students to read important essays related to each class session and then step back from discussions with leaders to write analytical essays, this course teaches students how to develop strong arguments based on solid logic and credible evidence, an essential component in making democracy work.

84-451 Policy Seminar II

All Semesters: 6 units

The Policy Seminar course takes a critical look at decision making in domestic politics and US foreign policy. It does so through weekly roundtable discussions with a diverse set of thought leaders. Based on intellectually significant essays that students are expected to read in advance of each class, these discussions give students an opportunity to ask probing questions about the three branches of the US government, media, embassies, advocacy groups, international organizations, and nongovernmental organizations. This course seeks to help students understand the responsibilities and activities that leaders and decision makers carry out on behalf of their organizations. Students are instructed in how to confidently and respectfully ask critical questions of those shaping policy. The term "roundtabling" is used to describe submitting an issue for critical discussion among relevant stakeholders. Knowing how to direct a roundtable is a significant element in the professional development of anyone interested in taking part in the policy arena, and this course helps students hone this important skill. In requiring students to read important essays related to each class session and then step back from discussions with leaders to write analytical essays, this course teaches students how to develop strong arguments based on solid logic and credible evidence, an essential component in making democracy work.

84-498 Undergraduate Research

Fall and Spring

Students conduct research under the supervision of a faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Prerequisite: Students must also complete an "Independent Study/Research for Credit" form, available from the Deputy Director or on the CMIST website. Permission of a faculty sponsor.

84-499 Independent Study

All Semesters

Students conduct independent academic study under the supervision of a faculty member. Students who wish to engage in an independent study should seek out a faculty member whose interests are appropriate to the topic. Students must also complete an "Independent Study/Research for Credit" form, available from the Deputy Director or on the CMIST website. Prerequisite: Permission of a faculty sponsor.

84-505 Undergraduate Internship

Fall and Spring

An internship is an approved and monitored work experience that can be related to an academic field of study through active reflection and specific learning goals. Students will be in regular contact with a faculty member, who will assign and evaluate academic work. Internships are available for 3, 6, or 9 units, depending on the type and amount of academic work produced. Students are responsible for finding their own internships and faculty sponsors, although assistance is available through the Deputy Director.

Department of Modern Languages

Anne Lambert, Department Head

Bonnie L. Youngs, Director of Undergraduate Studies

Location: Posner Hall, 341
www.cmu.edu/dietrich/modlang (<http://www.cmu.edu/dietrich/modlang/>)

Studying foreign languages and their cultures is desirable and essential for understanding our complex global world. It is crucial to educate global citizens who will be sensitive to other cultures and capable of communicating in other languages. Proficiency in a foreign language by itself, or combined with other professional training, may lead to a variety of rewarding careers. Moreover, the personal experience of mastering another language is enriching and gratifying.

Modern Languages Majors

These majors are designed to lead to acquisition of communicative language proficiency and substantive knowledge of other cultures.

Drawing on the unique interdisciplinary climate of the Carnegie Mellon campus, the undergraduate majors in Modern Languages encourage the acquisition of multiple skills by students with varied backgrounds, talents, and interests. An important resource in support of these goals is the Modern Language Resource Center (MLRC), a state-of-the-art facility that provides students with access to authentic foreign language materials such as original television broadcasts, interactive video projects, Technology Enhanced Language Learning (TELL) courses, international audio and video resources, and computerized assessment tools.

Students majoring in a modern language are also encouraged to enroll, preferably during their junior year, in a study-abroad program or to spend a summer abroad at a language institute or in an internship. Semester or year-long programs are available in places such as China, France, Germany, Japan, Africa, Russia, Spain, and Latin America. The Department also sponsors summer courses in China, Germany, and Spain. Foreign film series, informal conversation tables, native-speaker conversation partners, speaking and writing assistants, and Student Advisory Committee cultural events are some of the activities organized by the Department of Modern Languages to increase students' ability in languages and knowledge of cultures.

The major in Modern Languages is designed to permit students to acquire communicative language proficiency in their language of specialization. Courses in culture and civilization offer students a solid introduction to the main currents in national literatures as well as artistic and social movements. These courses integrate study of cultures with skill development in reading, writing, and aural/oral communication. In addition, the student who majors in Modern Languages will develop a perspective on the learning and use of second languages, from both a social and cognitive point of view, within contemporary American society and in an increasingly global community. Working closely with their advisor, language majors are guided to develop personal interests by taking courses in other disciplines such as fine arts, history, psychology, philosophy, and other humanities and social sciences, which often include readings, discussions, and papers in the foreign language. The rich technological environment of the campus strongly enhances all fields of language study.

Second language proficiency is an asset which provides students with practical as well as theoretical bases for a variety of paths after graduation. Students of Modern Languages have taken paths to a wide variety of careers in government, entrepreneurship and business, law, technology and engineering firms, media, public health, health policy, and health professions, non-profit organizations, entertainment and creative arts, and education. They are also prepared to pursue graduate studies in second language-related fields (e.g. linguistics, second language acquisition, literary and cultural studies).

Specializations within Modern Languages

Seven specializations are available in the Department of Modern Languages: Applied Multilingual Studies, Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Japanese Studies, and Russian Studies.

Language-specific faculty advisors for these majors are:

Applied Multilingual Studies: Dr. Bonnie Youngs, Teaching Professor of French & Francophone Studies; Applied Multilingual Studies

Chinese Studies - Dr. Gang Liu, Teaching Professor of Chinese Studies

French & Francophone Studies - Dr. Sebastien Dubreil, Teaching Professor of French and Francophone Studies, Second Language Acquisition and Technology-Enhanced Learning

German Studies - Dr. Stephen Brockmann, Professor of German
Hispanic Studies - Dr. Felipe Gómez, Teaching Professor of Hispanic Studies

Japanese Studies - Dr. Yoshihiro Yasuhara, Associate Teaching Professor of Japanese and Dr. Keiko Koda, Professor of Japanese and Second Language Acquisition

Russian Studies - Dr. Tatyana Gershkovich, Associate Professor of Russian Studies

The Major in Applied Multilingual Studies (108-114 units)

Faculty Advisor

Dr. Bonnie Youngs, Teaching Professor and Director of Undergraduate Studies (byoungs@cmu.edu)

Prerequisites

There are no prerequisites for this major. The core courses in the study of language and culture cannot be fulfilled with any placement credit transferred into Carnegie Mellon. Progress in language and culture will be accelerated by study abroad, which is highly recommended. (Study abroad advisor: Dr. Sebastien Dubreil, (sdubreil@andrew.cmu.edu)

Course Requirements

1. Complete four core courses in Modern Languages 36-42 units

| | | |
|--------|---|---|
| 82-xxx | Language and Culture Study (2 courses, 9-12 each) | |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-580 | Senior Seminar in Modern Languages | 9 |

2. Complete three courses in Foundations 27 units

| | | |
|--------|--|---|
| 76-293 | Writing about Research in Your Discipline | 9 |
| 80-180 | Nature of Language | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-383 | Language in Use | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |
| 82-180 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-217 | Multilingualism and Multiculturalism in the Arab World | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |

| | | |
|--------|--|------|
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |
| 82-288 | Everyday Learning: Designing Learning Exp in Times of Unrest & Uncertainty | Var. |

3. Complete five courses from the 'Theories & Concepts' and 'Data Analysis' list. Also possible are the following with advisor approval: 4 courses + thesis or 3 courses + Senior Honors Thesis. It is possible to count as one course either two minis (6 units each) or one mini plus an independent project (3 units)

82-3xx target language courses focusing on language/discourse (with advisor approval)

| | | |
|--------|---|---|
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-325 | Intertextuality | 9 |
| 76-386 | Language & Culture | 9 |
| 76-378 | Literacy: Educational Theory and Community Practice | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 82-382 | Introduction to Translation | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-481 | Translation Workshop 1 | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-482 | Introduction to Translation | 9 |
| 85-354 | Infant Language Development | 9 |
| 85-421 | Language and Thought | 9 |

82-4xx target language courses focusing on language/discourse (with advisor approval)

| | | |
|--------|---------------------------------|---|
| 76-314 | Data Stories | 9 |
| 76-380 | Methods in Humanities Analytics | 9 |

| | | |
|--------|--|------|
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-496 | Research Methods in Rhetoric & Writing Studies | 9 |
| 82-385 | Qualitative methods in SLA research | Var. |
| 82-388 | Topics in Second Language Acquisition | 9 |

Thesis options for 9 units

Senior Honors Thesis for 18 units

CPT for 9-18 units

Internship for 9-18 units

Sample Curriculum

Major in Applied Multilingual Studies (B.A.)

| Junior | | Senior | |
|---|-------------------------------------|---------------------|---|
| Fall | Spring | Fall | Spring |
| 82-283 Language Diversity & Cultural Identity | Language requirement, second course | Upper level (3xx) 1 | 82-580 Senior Seminar in Modern Languages |
| Language requirement, first course | Foundations 2 | Upper level (3xx) 2 | Upper level (4xx) 1 |
| Foundations 1 | Foundations 3 | Upper level (3xx) 3 | Upper level (4xx) 2 |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

The Major in Chinese Studies (96-99 units)

Faculty Advisors

Dr. Gang Liu, Associate Teaching Professor of Chinese Studies
(gangliu@andrew.cmu.edu (yyu@andrew.cmu.edu))

Prerequisites

Intermediate-level proficiency in the Chinese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor - Dr. Gang Liu, gangliu@andrew.cmu.edu (yyu@andrew.cmu.edu))

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the major advisor for a different curriculum that may accelerate their completion of the requirement.

Students may double count four courses taken for the Chinese Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Course Requirements

1. Core Courses in Chinese Studies (36-39 units*)

Complete all four courses

| | | Units |
|--------|--|-------|
| 82-232 | Intermediate Chinese II (may be substituted by 82-235 Fables, Legends & Stories from Ancient Chinese Civilization) | 12 |
| 82-331 | Reading Into a New China I: Population, Youth, Marriage, & Housing | 9 |
| 82-332 | Reading Into a New China II: Transportation, Education, Pop Culture, & Health | 9 |
| 82-333 | Chinese Language and Culture | 9 |

*Students who place out of 82-232/82-235 must take a minimum of 9 additional units chosen from List A Electives.

2. Core Courses in Modern Languages (18 units)

Complete one 9 unit course* plus the Senior Seminar (9 units) in the spring of the senior year.

| | | Units |
|--------|---|-------|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| 82-580 | Senior Seminar in Modern Languages | 9 |

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in Chinese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Core Courses in Chinese History & Society (9 units)

Complete one course after consultation with the major advisor and the designated History or Modern Languages professor.

| | | Units |
|--------|---|-------|
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| 82-230 | Cultural Topics in Chinese Studies | 6 |
| 82-138 | Comparative China: Perceptions Through Youtube & TikTok | 9 |
| 82-234 | Topics in Chinese History | 9 |
| 82-238 | Topics in Chinese Culture | 9 |

4. Chinese Studies and Interdisciplinary Electives (36 units)

Complete two courses (18 units) from List A and two courses (18 units) from List B, or two courses (18 units) from List A, one (9 units) from List B, and one (9 units) from List C.

List A. Core Chinese Studies Electives (18 units)

| | | Units |
|------------|---|-------|
| 82-432 | Chinese Popular Culture: A Game of Learning | 9 |
| 82-433 | Topics in Contemporary Culture of China * | 9 |
| 82-434 | Studies in Chinese Traditions * | 9 |
| 82-436 | Introduction to Classical Chinese | 9 |
| 82-439 | Modern China Through Literature * | 9 |
| 82-440 | Studies in Chinese Literature & Culture * | 9 |
| 82-531/532 | Special Topics in Chinese Studies * | Var. |
| 82-533 | Cultural Topics in Chinese Studies | 6 |

*Students may repeat these courses with new topics.

List B: Chinese Studies Electives (minimum 9 units)

| | | Units |
|--------|--|-------|
| 82-235 | Fables, Legends and Stories from Ancient Chinese Civilization *if using for List B, another course on List B must be chosen from the same list, not List C. | 9 |
| 82-334 | Structure of Chinese | 9 |
| 82-335 | Chinese Culture Through Legends and Folktales | 9 |
| 82-337 | Mandarin Chinese for Oral Communication I | 9 |
| 82-338 | Mandarin Chinese for Oral Communication II | 9 |
| 82-339 | Business Language & Culture in China I | 9 |
| 82-340 | Business Language & Culture in China II | 9 |
| 82-431 | China and the West | 9 |
| 82-432 | Chinese Popular Culture: A Game of Learning | 9 |
| 82-433 | Topics in Contemporary Culture of China * | 9 |
| 82-434 | Studies in Chinese Traditions * | 9 |

| | | |
|------------|---|------|
| 82-436 | Introduction to Classical Chinese | 9 |
| 82-440 | Studies in Chinese Literature & Culture | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-531/532 | Special Topics in Chinese Studies * | Var. |
| 82-533 | Cultural Topics in Chinese Studies | 6 |

* Students may repeat these courses with new topics.

List C. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Chinese Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|-----------------------------|--|-------|
| Architecture | | Units |
| 48-551 | Ethics and Decision Making in Architecture | 9 |
| Art | | Units |
| 60-399 | Art History/Theory Independent Study | 9 |
| Business | | Units |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| English | | Units |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-386 | Language & Culture | 9 |
| History | | Units |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| Modern Languages | | Units |
| 82-137 | Chinese Calligraphy: Culture and Skills | 9 |
| 82-138 | Comparative China: Perceptions Through Youtube & TikTok | 9 |
| 82-180 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-198 | Research Training: Modern Languages | Var. |
| 82-230 | Cultural Topics in Chinese Studies | 6 |
| 82-234 | Topics in Chinese History | 9 |
| 82-238 | Topics in Chinese Culture | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | Units |
| 80-180 | Nature of Language | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | Units |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |
| Social and Decision Science | | Units |
| 88-411 | Rise of the Asian Economies | 9 |
| 88-415 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |

5. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 Dietrich College Senior Honors Thesis I/66-502 Dietrich College Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Chinese and a 3.25 QPA overall)

Sample Curriculum

This sample curriculum assumes that all prerequisites for 82-331 are fulfilled prior to the Junior year.

| Third-Year | | Fourth-Year | |
|---|--|--|---|
| Fall | Spring | Fall | Spring |
| 82-331 Reading Into a New China I: Population, Youth, Marriage, & Housing | 82-332 Reading Into a New China II: Transportation, Education, Pop Culture, & Health | Core Chinese Studies Elective From List A | |
| 82-333 Chinese Language and Culture | Core History and Society Elective | Chinese Studies Elective From List B | 82-580 Senior Seminar in Modern Languages |
| Modern Languages core course or equivalent approved by advisor | Chinese Studies Elective From List B or Interdisciplinary Elective From List C | Chinese Studies Elective From List B or Interdisciplinary Elective From List C | Elective |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in French and Francophone Studies (99 units)

Faculty Advisor

Dr. Sébastien Dubreil, Teaching Professor of French and Francophone Studies, Second Language Acquisition and Technology-Enhanced Learning (sdubreil@andrew.cmu.edu (byoungs@cmu.edu))

Prerequisites

Elementary-level proficiency in French. This is equivalent to the completion of two 12-unit courses. Exemption from elementary or intermediate level courses can be awarded based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. If students place out of the intermediate level, then additional courses at the 300 and 400 levels will be required to complete the minor. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors.

Students may double count four courses taken for the French & Francophone Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Course Requirements

1. Complete two courses at the intermediate level (18 units)

| | | |
|--------|-----------------------|------------|
| 82-201 | Intermediate French I | Units 9 |
|--------|-----------------------|------------|

| | | |
|--------|------------------------|---|
| 82-202 | Intermediate French II | 9 |
|--------|------------------------|---|

***Students placing out of the intermediate level must take two additional courses at the 300 or 400 level.**

2. Complete two or three courses at the 300-level and two or three courses at the 400-level (45 units)

| | | |
|--------|--|-------|
| | | Units |
| 82-303 | French & Francophone Cultures * | 9 |
| 82-304 | French & Francophone Sociolinguistics * | 9 |
| 82-415 | Topics in French and Francophone Studies * | 9 |
| 82-416 | Topics in French and Francophone Studies * | 9 |
| 82-501 | Special Topics in French & Francophone Studies * | Var. |
| 82-502 | Special Topics in French & Francophone Studies * | Var. |
| 82-505 | Modern Languages Undergraduate Internship | Var. |

***Students may repeat these courses with new topics.**

3. Complete two required classes in Modern Languages (18 units)

| | | |
|--------|--|-------|
| | | Units |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-580 | Senior Seminar in Modern Languages | 9 |

4. Complete two electives, one in Modern Languages and one from the following list, or two in Modern Languages. (18 units)

| | | |
|------------------|--|-------|
| | | Units |
| Architecture | | |
| 48-338 | European Cities in the XIX Century: Planning, Architecture, Preservation | 9 |
| 48-340 | Modern Architecture and Theory 1900-1945 | 9 |
| 48-341 | Expression in Architecture | 9 |
| 48-448 | History of Sustainable Architecture | 9 |
| English | | Units |
| 76-239 | Introduction to Film Studies | 9 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-386 | Language & Culture | 9 |
| History | | Units |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-350 | Early Christianity | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| Modern Languages | | Units |
| 82-180 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-227 | Germany & the European Union | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Music | | Units |
| 57-173 | Survey of Western Music History | 9 |
| 57-306 | World Music | 9 |
| 57-441 | Analysis of 19th Century Music | 9 |
| Philosophy | | Units |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |

| | | |
|------------------------------|---------------------------|-------|
| 80-380 | Philosophy of Language | 9 |
| 80-381 | Meaning in Language | 9 |
| Psychology | | Units |
| 85-241 | Social Psychology | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |
| Social and Decision Sciences | | Units |
| 88-419 | International Negotiation | 9 |

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad or internship is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 Dietrich College Senior Honors Thesis I/66-502 Dietrich College Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in French and a 3.25 QPA overall)

Sample Curriculum

| First-Year or Second-Year | | Third-Year | |
|---|----------------------------------|--|---|
| Fall | Spring | Fall | Spring |
| 82-201 Intermediate French I | 82-202 Intermediate French II | 82-303 French & Francophone Cultures | 82-303 or 82-304 with new topic or FFS 400-level course |
| 82-283 Language Diversity & Cultural Identity | ML or interdisciplinary elective | 82-304 French & Francophone Sociolinguistics | ML elective course or elective approved by advisor |
| | Elective | Elective | Elective |
| | Elective | Elective | Elective |
| | Elective | Elective | Elective |
| Fourth-Year | | | |
| Fall | | Spring | |
| French & Francophone Studies (FFS) 4xxx required course | | French & Francophone Studies 4xx required course | |
| Elective | | 82-580 Senior Seminar in Modern Languages | |
| Elective | | Elective | |
| Elective | | Elective | |
| Elective | | Elective | |

This is presented as a three-year (sophomore-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in German Studies (93 units)

Faculty Advisor

Dr. Stephen Brockmann, Professor of German Studies
(smb@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor: Dr. Gabriele Eichmanns Maier, eichgabi@andrew.cmu.edu)

Students may double count four courses taken for the German Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Course Requirements

1. Core Courses in German Studies (36 units)

Complete all four courses.*

| | | |
|--------|--|-------|
| | | Units |
| 82-221 | Intermediate German I | 9 |
| 82-222 | Intermediate German II | 9 |
| 82-320 | Contemporary Society in Germany, Austria and Switzerland | 9 |
| 82-323 | Germany, Austria and Switzerland in the 20th Century | 9 |

*Students who place out of one or both of the intermediate-level classes would still need to take the equivalent number of units at the 300 or 400-level.

2. Core Courses in Modern Languages (18 units)

Complete one 9-unit course* in Modern Languages, plus the Senior Seminar (9 units) in spring of the senior year.

| | | |
|--------|---|-------|
| | | Units |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| 82-580 | Senior Seminar in Modern Languages | 9 |

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in German Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. German Studies and Interdisciplinary Electives (54 units)

Complete five courses (45 units) from List A and one (9 units) from List B, or a minimum of three courses (27 units) from List A and one or two courses (9-18 units) from List B. The student may complete an additional 3 units of coursework in German to allow a List B elective to count as a List A elective, with permission of the major advisor and the course instructor.

List A. German Electives

| | | |
|------------|--|-------|
| | | Units |
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-425/426 | Topics in German Literature and Culture * | 9 |
| 82-426 | Topics in German Literature and Culture | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-429 | German Reading and Translation Workshop: German in Today's World | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |

| | | |
|------------|------------------------------------|------|
| 82-521/522 | Special Topics in German Studies * | Var. |
| 82-522 | Special Topics in German Studies | Var. |

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

From possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the German Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|------------------|--|-------|
| Architecture | | Units |
| 48-338 | European Cities in the XIX Century: Planning, Architecture, Preservation | 9 |
| 48-340 | Modern Architecture and Theory 1900-1945 | 9 |
| 48-350 | Postwar Modern Architecture and Theory | 9 |
| English | | Units |
| 76-239 | Introduction to Film Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-387 | Writing in the Disciplines | 6 |
| 76-483 | Research Methods in Technical & Professional Communication | 9 |
| History | | Units |
| 79-205 | 20th Century Europe | 9 |
| 79-256 | Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990 | 9 |
| 79-257 | Germany and the Second World War | 9 |
| Modern Languages | | Units |
| 82-227 | Germany & the European Union | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-427 | Nazi and Resistance Culture (when taken entirely in English) | 9 |
| 82-428 | History of German Film (when taken entirely in English) | 9 |
| 82-480 | Translation Technologies | 9 |
| Music | | Units |
| 57-306 | World Music | 9 |
| Philosophy | | Units |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-180 | Nature of Language | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-256 | Modern Moral Philosophy | 9 |
| 80-275 | Metaphysics | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | Units |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 Dietrich College Senior Honors Thesis I/66-502 Dietrich College Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in German and a 3.25 QPA overall)

Sample Curriculum

| Third-Year | | Fourth-Year | |
|---|---|---|---|
| Fall | Spring | Fall | Spring |
| 82-320 Contemporary Society in Germany, Austria and Switzerland | 82-323 Germany, Austria and Switzerland in the 20th Century | German Studies Elective From List A | German Studies Elective From List A |
| 82-327 The Emergence of the German Speaking World | Interdisciplinary Elective From List B | German Studies Elective From List A | German Studies Elective From List A or Interdisciplinary Elective From List B |
| Modern Languages core course or equivalent approved by advisor | Elective | German Studies Elective From List A or Interdisciplinary Elective From List B | 82-580 Senior Seminar in Modern Languages |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Hispanic Studies (99 units)

Faculty Advisor

Dr. Felipe Gómez, Teaching Professor of Hispanic Studies (fgomez@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or Carnegie Mellon internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor: Dr. Therese Tardio, tardio@andrew.cmu.edu)

Students may double count four courses taken for the Hispanic Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include courses taken towards General Education requirements, which have no limit.

Course Requirements

1. Core Courses in Hispanic Studies (27 units)

Complete two courses.

| | | | |
|--------|------------------------------------|---|-------|
| 82-342 | Spain: Language and Culture | 9 | Units |
| 82-343 | Latin America Language and Culture | 9 | |
| 82-344 | U.S. Latinos: Language and Culture | 9 | |

Complete required course.

| | | | |
|--------|--|---|-------|
| 82-345 | Introduction to Hispanic Literary and Cultural Studies | 9 | Units |
|--------|--|---|-------|

2. Core Courses in Modern Languages (18 units)

Complete one 9-unit course* in Modern Languages, plus the Senior Seminar (9 units) in spring of the senior year.

| | Units |
|--|-------|
| 82-280 Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 Contextual Thinking | 9 |
| 82-282 Interpreting Global Texts & Cultures | Var. |
| 82-283 Language Diversity & Cultural Identity | 9 |
| 82-284 Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 Cultural Complexities | 9 |
| 82-383 Second Language Acquisition: Theories and Research | 9 |
| 82-388 Topics in Second Language Acquisition | 9 |
| 82-480 Translation Technologies | 9 |
| 82-580 Senior Seminar in Modern Languages | 9 |

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or the acquisition of language and culture from the listings in Hispanic Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Hispanic Studies and Interdisciplinary Electives (54 units)

Complete six courses (54 units) from or five courses (45 units) from List A and one (9 units) from List B.

List A. Hispanic Studies Electives

| | Units |
|---|-------|
| 82-441 Studies in Peninsular Literature and Culture * | 9 |
| 82-443 Spanish Reading and Translation Workshop | 9 |
| 82-444 The Structure of Spanish | 6 |
| 82-451 Studies in Latin American Literature and Culture | 9 |
| 82-455/456 Topics in Hispanic Studies * | 9 |
| 82-506 Hispanic Studies Internship | Var. |
| 82-541/542 Special Topics in Hispanic Studies * | Var. |

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

From possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Hispanic Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

| | |
|--|-------|
| Architecture | Units |
| 48-348 Architectural History of Mexico & Guatemala | 9 |
| English | Units |
| 76-385 Introduction to Discourse Analysis | 9 |
| 76-386 Language & Culture | 9 |
| 76-387 Writing in the Disciplines | 6 |
| 76-484 Discourse Analysis | 9 |
| History | Units |
| 79-223 Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-224 Mayan America | 9 |
| 79-237 Comparative Slavery | 9 |
| 79-288 Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-276 Beyond the Border | 9 |
| Institute for Policy and Strategy | Units |
| 84-306 Latin American Politics | 9 |
| Modern Languages | Units |
| 82-245 New Directions in Hispanic Studies | 9 |
| 82-247 US Latinos Literature | 9 |
| 82-249 Hispanic Language & Cultures for the Professions | 9 |
| 82-280 Bilingual & Bicultural Experiences in the US | 9 |

| | |
|--|-------|
| 82-281 Contextual Thinking | Var. |
| 82-282 Interpreting Global Texts & Cultures | Var. |
| 82-283 Language Diversity & Cultural Identity | 9 |
| 82-284 Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 Cultural Complexities | 9 |
| 82-383 Second Language Acquisition: Theories and Research | 9 |
| 82-388 Topics in Second Language Acquisition | 9 |
| 82-480 Translation Technologies | 9 |
| Music | Units |
| 57-306 World Music | 9 |
| Philosophy | Units |
| 80-180 Nature of Language | 9 |
| 80-280 Linguistic Analysis | 9 |
| 80-285 Natural Language Syntax | 9 |
| 80-286 Words and Word Formation: Introduction to Morphology | 9 |
| 80-380 Philosophy of Language | 9 |
| 80-381 Meaning in Language | 9 |
| Psychology | Units |
| 85-375 Crosscultural Psychology | 9 |
| 85-421 Language and Thought | 9 |

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 Dietrich College Senior Honors Thesis I/66-502 Dietrich College Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Hispanic Studies and a 3.25 QPA overall)

Sample Curriculum

| Third-Year | | Fourth-Year | |
|--|---|---|---|
| Fall | Spring | Fall | Spring |
| 82-342 Spain: Language and Culture | 82-345 Introduction to Hispanic Literary and Cultural Studies | Hispanic Studies Elective From List A | Hispanic Studies Elective From List A |
| 82-343 Latin America Language and Culture | Interdisciplinary Elective From List B | Hispanic Studies Elective From List A | Hispanic Studies Elective From List A |
| Modern Languages core course or equivalent approved by advisor | Elective | Hispanic Studies Elective From List A or Interdisciplinary Elective from List A or List B | 82-580 Senior Seminar in Modern Languages |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Japanese Studies (108-111 units)

Faculty Advisors

Dr. Yoshihiro Yasuhara, Associate Teaching Professor of Japanese Studies
(yyasuhar@andrew.cmu.edu (yiwasaki@andrew.cmu.edu))
Dr. Keiko Koda, Professor of Japanese Studies and Second Language
Acquisition (kkoda@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Japanese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, Cambridge GCE Advanced level, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all majors. (Study abroad advisor - Dr. Yasufumi Iwasaki, yiwasaki@andrew.cmu.edu)

Students may double count four courses taken for the Japanese Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include the courses taken to fulfill General Education requirements, which have no limit.

Course Requirements

1. Core Courses in Japanese Studies (36-39 units)

Complete all four courses.

| | | Units |
|--------|---|-------|
| 82-272 | Intermediate Japanese II * | 12 |
| 82-273 | Introduction to Japanese Language and Culture | 9 |
| 82-371 | Changes in Japan 1: Food and Work Cultures | 9 |
| 82-372 | Advanced Japanese II | 9 |

*Students who place out of 82-272 Intermediate Japanese II must take 9 units chosen from List A electives.

2. Core Courses in Modern Languages (18 units)

Complete one 9-unit course* in Modern Languages, plus the Senior Seminar (9 units) in spring of the senior year.

| | | Units |
|--------|--|-------|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| 82-580 | Senior Seminar in Modern Languages | 3 |

* In consultation with the major advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or the acquisition of language and culture from the listings in Japanese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought.

3. Japanese Studies and Interdisciplinary Electives (54 units)

Complete four courses (36 units) from List A and two (18 units) from List B. With permission of the major advisor, students are encouraged to complete at least one Japanese history course that qualifies for List A or List B at the University of Pittsburgh, one in Japan when they study abroad, or in a summer program at any other university.

List A. Japanese Electives

| | | Units |
|------------|---|-------|
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-473/474 | Topics in Japanese Studies | 9 |

| | | |
|------------|---|------|
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-571/572 | Special Topics in Japanese Studies * | Var. |

* Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their major advisor for the most up to date interdisciplinary electives appropriate for the Japanese Studies curriculum. Courses may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|------------------|---|-------|
| English | | Units |
| 76-239 | Introduction to Film Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-387 | Writing in the Disciplines | 6 |
| History | | Units |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| Modern Languages | | Units |
| 82-234 | Topics in Chinese History | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-279 | Anime - Visual Interplay between Japan and the World | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Music | | Units |
| 57-306 | World Music | 9 |
| Philosophy | | Units |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | Units |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

4. Oral Proficiency Interview

Complete an oral proficiency interview. At the latest, this exam should be scheduled by midterm of the senior spring semester. Students are permitted to retake the test.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options.

Senior Honors Thesis

Modern Languages majors are encouraged to undertake a Senior Honors Thesis (82-591/82-592 Modern Languages Honors Thesis or 66-501 Dietrich College Senior Honors Thesis I/66-502 Dietrich College Senior Honors Thesis II). The Honors Thesis program provides qualified seniors with a valuable opportunity to combine their academic and personal experiences and interests into a unique research project. (Prerequisites: a 3.5 QPA in Japanese Studies and a 3.25 QPA overall)

Sample Curriculum

This sample curriculum assumes that all prerequisites for 82-371 are fulfilled prior to the junior year.

| Third-Year | | Fourth-Year | |
|--|--|---------------------------------------|---|
| Fall | Spring | Fall | Spring |
| 82-273 Introduction to Japanese Language and Culture | 82-372 Advanced Japanese II | Japanese Studies Elective from List A | Japanese Studies Elective From List A) |
| 82-371 Changes in Japan 1: Food and Work Cultures | Modern Languages core course of equivalent approved by advisor | Japanese Studies Elective from List A | Japanese Studies Elective From List B |
| Modern Languages core course of equivalent | Interdisciplinary Elective from List B | Elective | 82-580 Senior Seminar in Modern Languages |
| Elective | Interdisciplinary Elective from List B | Elective | Elective |
| Elective | Elective | Elective | Elective |
| | Elective | | |

This is presented as a two-year (junior-senior) plan for completing the major requirements. It is intended to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

The Major in Russian Studies (93-99 or 108-111 for students with no prior studies in Russian)

Faculty Advisor

Dr. Tatyana Gershkovich, Associate Professor of Russian Studies

The major in Russian Studies is jointly administered by the Departments of History and Modern Languages. Students are required to fulfill requirements in history and in language and culture.

Prerequisites

The major in Russian Studies is an interdepartmental, interdisciplinary major jointly administered by the Departments of History and Modern Languages. Students are asked to fulfill requirements in history and in language and culture. Additionally, students are strongly encouraged to study abroad in Russia or other parts of the Russian-speaking world. Not only does study abroad offer students a memorable and formative experience of cultural immersion, it also helps them advance to their highest possible levels of linguistic and cultural competence by the time they graduate.

Students may double count four courses taken for the Russian Studies major that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include course that count toward General Education requirements, which have no limit.

Course Requirements

1. Required Courses in Russian Language (36-48 units)

| Modern Languages | |
|------------------|----------------------------|
| 82-191 | Elementary Russian I 12 |
| 82-192 | Elementary Russian II 12 |
| 82-291 | Intermediate Russian I 12 |
| 82-292 | Intermediate Russian II 12 |

N.B. Students with native or near-native proficiency in Russian or with prior study at elementary or intermediate levels may begin language study at a higher level. Students with previous experience in Russian will need to complete a minimum of 36 units which can include adding 3-unit language enrichment credits to content-based courses.

2. Required Courses in Russian Culture (24 units)

Complete two courses. These courses are conducted in English. Russian Studies majors must complete the additional 3-units of work for each course.

| Modern Languages | |
|------------------|--|
| 82-294 | 19th Century Russian Masterpieces Var. |
| 82-295 | 20th Century Russian Masterpieces Var. |

3. Required Electives in History (18 units)

| Complete two courses. | | Units |
|-----------------------|---|-------|
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |

4. Required Elective (9-12 units)

Complete one course. Courses not listed below may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester. Courses marked by * are offered in English and Russian Studies majors must complete the additional 3-units of work for each course. All other courses are 9 units.

| | | |
|--------|---|------|
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-322 | Stalin and the Great Terror | 9 |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | Var. |
| 82-391 | Advanced Russian I - Berlin, Paris, New York, Harbin | 9 |
| 82-392 | Advanced Russian II: Great Short Works | 9 |
| 82-394 | Russian for Heritage Speakers: Babushka's Russia & Beyond | 9 |
| 82-397 | Radicals, Heretics, Hackers: Russian Outlaws in History, Literature, and Film | Var. |

5. Required Senior Thesis (9 units)

In their senior year, majors must complete a 20–25 page independent research or translation project making use of Russian sources. For this project, students may choose to work closely with a professor in History (79-491) or in Modern Languages (82-599). This in-depth research project offers students a unique opportunity to complete a piece of original scholarship in their areas of interest, and to develop an expertise with which to embark on future intellectual and professional pursuits. The number of credits for the thesis reflects the expectation that students will do significant work in Russian and use the project to advance their linguistic competence.

Recent theses topics have included:

- *A Russian Academic Network: An Interdisciplinary Evaluation of Realism in Russian Foreign Policy Academia*
- *Khrushchev, de-Stalinization, and the Twentieth Congress of the Communist Party*
- *Lunokhod and the Soviet Space Program*
- *Constructivism and New Sight: A Rhetorical Analysis of the Early Soviet Political Poster*
- *Alexander Rodchenko and the Development of Constructivism in Russian Art*
- *Boris Akunin and Contemporary Russian Fiction*

Dietrich College Honors Senior Thesis

Students who meet the eligibility requirements may extend their Russian Studies Thesis (9 units) into a Dietrich College Honors Thesis (18 units) with the approval of their advisor. Information on this program can be found at <http://www.cmu.edu/dietrich/undergraduate/programs/shp/>

Highly Recommended Opportunities for Majors

Study Abroad

Students are strongly encouraged to spend a semester or summer in Russia through an approved exchange program. Consult with your advisor and the Office of International Education (OIE) about possible options. Many exchange programs offer instruction at internationally recognized universities in Russian language, history, literature, and culture. They also offer travel to ancient sites and cities, visits to museums, palaces, exhibitions, and monuments, and the opportunity to live with a Russian host family. Scholarship opportunities are available.

Senior Seminar in Modern Languages

82-580 Senior Seminar in Modern Languages (9 units)

The senior seminar, offered in the senior spring semester, brings together majors from all of Modern Languages. In addition to offering students strategies for maintaining and advancing their language skills after they graduate, this course provides an occasion for students to reflect on their own language-learning experiences. Students are prompted to consider larger issues surrounding language learning and multiculturalism in the United States and globally.

Faculty Exchange Program

In 1993, the College of Humanities and Social Sciences at CMU initiated a faculty exchange program with the Russian State University of the Humanities (RGGU), one of the foremost universities in Russia, located in Moscow. Carnegie Mellon has hosted faculty members from RGGU specializing in history, language, and philosophy. These professors have joined our departments for a semester, offering unique courses on subjects not generally available to our students. Faculty members from Carnegie Mellon have visited Moscow, using the RGGU exchange to pursue archival research, attend conferences, and collaborate on common projects. The exchange offers students an opportunity to study language from native speakers, gain exposure to different perspectives on history and politics, and gather firsthand knowledge about recent developments in Russia. In addition, the exchange can provide important contacts for students interested in pursuing careers abroad.

Sample Curriculum

| First-Year or Second-Year | | Third-Year | |
|---|--|--|--------------------------------|
| Fall | Spring | Fall | Spring |
| 82-191 Elementary Russian I | 82-192 Elementary Russian II | 82-291 Intermediate Russian I | 82-292 Intermediate Russian II |
| 79-265 Russian History: Game of Thrones | 79-266 Russian History and Revolutionary Socialism | Required elective in Modern Languages or History | Elective |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

| Fourth-Year | |
|--|---|
| Fall | Spring |
| 82-399 Equity & Justice in Modern Languages (Language-Specific) | 82-294 19th Century Russian Masterpieces |
| 82-293 Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 82-599 Russian Studies Thesis |
| Elective | Required Elective |
| Elective | 82-580 Senior Seminar in Modern Languages |
| Elective | Elective |
| Elective | Elective |

This is presented as a two-year (junior-senior) plan for completing the major requirements. Its purpose is to show that this program can be completed in as few as two years, not that it must be. Students may enter their major and begin major course requirements as early as the start of the sophomore year, and in some instances in the first year. Students should consult their advisor when planning their program.

This plan is also an example of the suggested sequence of study for students who have had little or no prior exposure to the language. Such students would need to satisfy the prerequisites (elementary and intermediate language study) during their freshman and sophomore years.

Modern Languages as an Additional Major

In addition to their primary major, a student may complete a major in Applied Multilingual Studies, Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Japanese Studies, and Russian Studies. Students outside of Dietrich College interested in an additional major in Modern Languages need to fulfill only the requirements for the Modern Languages major but not the Dietrich College General Education requirements.

Minors in the Department of Modern Languages

The Department of Modern Languages also offers minors in Applied Multilingual Studies, Arabic Studies, Chinese Studies, French and Francophone Studies, German Studies, Hispanic Studies, Immersive Technologies in Arts & Culture, Japanese Studies, and Russian Studies. A minor in one of these language and culture areas requires core courses similar to the major and includes a variety of options for electives. Many students study abroad as part of their program. Students who minor in Modern Languages have found the program an enriching complement to their major areas of study and an asset to their work in government, entrepreneurship and business, law, technology and engineering firms, media, public health, health policy, and health professions, non-profit organizations, entertainment and creative arts, and education.

Curriculum

The minimum requirement for the minor in French and Francophone Studies, German Studies or Hispanic Studies is 54 units (not including any 100- or 200-level prerequisite work in the chosen language), as outlined below. The minimum requirement for the minor in Applied Multilingual Studies, Arabic Studies, Chinese Studies, Japanese Studies or Russian Studies is 54-60 units, depending on the student's language background.

Language-specific faculty advisors for these specializations are:

Applied Multilingual Studies - Dr. Bonnie Youngs, Teaching Professor of French & Francophone Studies; Applied Multilingual Studies

Arabic Studies - Dr. Khaled Al Masaeed, Associate Professor of Arabic Studies (**Pittsburgh**) and Dr. Zeinab Ibrahim, Teaching Professor of Arabic Studies (**Qatar**)

Chinese Studies - Dr. Gang Liu, Teaching Professor of Chinese Studies, Dr. Sue-mei Wu, Teaching Professor of Chinese Studies, and Tianxue Yao, Lecturer of Chinese Studies

French & Francophone Studies - Dr. Bonnie Youngs, Teaching Professor of French & Francophone Studies; Applied Multilingual Studies

German Studies - Dr. Gabriele Eichmanns Maier, Teaching Professor of German Studies

Hispanic Studies - Dr. Therese Tardio, Teaching Professor of Hispanic Studies

Immersive Technologies in Arts & Culture - Ryan McKelvey (IDeATe)

Japanese Studies - Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese and Dr. Yoshihiro Yasuhara, Associate Teaching Professor of Japanese Studies

Russian Studies - Dr. Tatyana Gershkovich, Associate Professor of Russian Studies

The Minor in Applied Multilingual Studies (54-57 units)

Faculty Advisor

Dr. Bonnie Youngs, Teaching Professor and Director of Undergraduate Studies (byoungs@cmu.edu)

Prerequisites

There are no prerequisites for this minor. The core course in the study of language and culture cannot be fulfilled with any placement credit transferred into Carnegie Mellon. Progress in language and culture will be accelerated by study abroad, which is highly recommended. (Study abroad advisor - Dr. Sébastien Dubreil, sdubreil@andrew.cmu.edu.)

COURSE REQUIREMENTS

1. Complete two core courses in Modern Languages (18-21 units)

- 82-xxx Language and culture study 9-12 units

2. Complete four courses in Foundations, Theory & Concepts, and Data Analysis. Choose four courses, at least one at the 3xx level and one at the 4xx level. One course outside of Modern Languages can be counted. It is possible to count as one course either two minis (6 units each) or one mini plus an independent project (3 units). (36 units)

- Foundation Courses in Modern Languages
- Foundations electives outside of Modern Languages
- Theories & Concepts Courses in Modern Languages
- Theories & Concepts Courses outside of Modern Languages
- Data Analysis Courses in Modern Languages
- Data Analysis electives outside of Modern Languages

The Minor in Arabic Studies (54-57 units)

Faculty Advisors

Dr. Khaled Al Masaeed, Associate Professor of Arabic Studies
(masaeed@andrew.cmu.edu) (**Pittsburgh**)
Dr. Zeinab Ibrahim, Teaching Professor of Arabic Studies
(zeinab@qatar.cmu.edu) (**Qatar**)

Prerequisites

Pittsburgh Campus: Intermediate-level proficiency in the Arabic language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Khaled Al Masaeed (masaeed@andrew.cmu.edu).

Qatar Campus: Advanced-level proficiency in the Arabic language. CMU-Q students who need elementary and intermediate level courses should consult with the campus advisor for Arabic Studies before declaring the minor. Student progress may be accelerated or supplemented by study abroad. (Study abroad advisor for Qatar - Dr. Zeinab Ibrahim (zeinab@qatar.cmu.edu).

Students may double count one course taken for the Arabic Studies minor that are also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the minor advisors for a different curriculum that may accelerate their completion of the requirement.

Course Requirements

1. Core Courses in Arabic Studies (27-30 units)

Complete three courses.*

| | | |
|--------|------------------------|----|
| 82-212 | Intermediate Arabic II | 12 |
| 82-311 | Advanced Arabic I | 9 |
| 82-312 | Advanced Arabic II | 9 |

*Students who place out of 82-212 must take a total of 27 units in Core Courses

2. Arabic Studies and Interdisciplinary Electives (27 units)

Pittsburgh: Complete two courses (18 units) from List A and one course (9 units) from List B, or three courses (27 units) from List A.

Qatar: Complete four courses (36 units) from List A, and two courses (18 units) from List B, or five courses (45 units) from List A and one course (9 units) from List B, or six courses (54 units) course from List A.

List A. Electives

| | | |
|--------|--|------|
| 82-117 | Arabic Conversation & Dialect I | 6 |
| 82-118 | Arabic Conversation & Dialect II | 6 |
| 82-313 | Topics in Modern Arabic Language, Literature and Culture (CMU-Q) | 9 |
| 82-314 | Literature of the Arabic-speaking World (CMU-Q) | 9 |
| 82-411 | Topics in Arabic Media * | Var. |
| 82-412 | Topics in Arabic Studies * | 9 |
| 82-417 | Arabic for the Professions II (CMU-Q) | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-511 | Special Topics in Arabic Studies * | 9 |
| 82-512 | Special Topics in Arabic Studies: Advanced Grammar Workshop | 9 |

*Students may repeat these courses with new topics with the instructor's permission.

List B. Interdisciplinary Electives

| | | |
|--------------|---|---|
| Architecture | | |
| 48-240 | History of World Architecture, I | 9 |
| 48-315 | Environment I: Climate & Energy in Architecture | 9 |

| | | |
|-------------------------|---|---|
| Business Administration | | |
| 70-321 | Negotiation and Conflict Resolution | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |

| | | |
|-------------------------------|--|---|
| Engineering and Public Policy | | |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |

| | | |
|---------|---|---|
| English | | |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-472 | Topics in Journalism: Storytelling in a Digital Age | 9 |
| 76-386 | Language & Culture | 9 |
| 76-484 | Discourse Analysis | 9 |
| 76-491 | Rhetorical Analysis | 9 |

| | | |
|---------|---|---|
| History | | |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 6 |

| | | |
|---------------------|---------------------------------------|---|
| Information Systems | | |
| 67-329 | Contemporary Themes in Global Systems | 9 |

| | | |
|-------------------------------------|---|---|
| Institute for Politics and Strategy | | |
| 84-275 | Comparative Politics | 9 |
| 84-310 | International Political Economy | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-389 | Terrorism and Insurgency | 9 |

| | | |
|-------------|---------------------------|---|
| Linguistics | | |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |

| | | |
|------------------|--|------|
| Modern Languages | | |
| 82-114 | Arabic for Global Exchange Online | 6 |
| 82-214 | Topics in Modern Arabic Language, Literature, & Culture (CMU-Q) | 9 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | Var. |
| 82-216 | Literature of the Arabic-speaking World (CMU-Q) | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-300 | Language & Society in the Arab World | 9 |
| 82-313 | Topics in Modern Arabic Language, Literature and Culture (CMU-Q) | 9 |
| 82-314 | Literature of the Arabic-speaking World (CMU-Q) | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-411 | Topics in Arabic Media | Var. |
| 82-412 | Topics in Arabic Studies | 9 |
| 82-480 | Translation Technologies | 9 |
| 82-448 | Topics in Arabic Language, Literature, & Culture (CMU-Q) | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |

| | | |
|------------|--|---|
| Philosophy | | |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-324 | Philosophy of Economics | 9 |

| | | |
|------------|-----------------------------------|---|
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |
| Psychology | | |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

The Minor in Chinese Studies (54-57 units)

Faculty Advisors

Dr. Gang Liu, Teaching Professor of Chinese Studies
(gangliu@andrew.cmu.edu)
Dr. Sue-mei Wu, Teaching Professor of Chinese Studies
(suemei@andrew.cmu.edu)
Tianxue Yao, Lecturer of Chinese Studies (tyao@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Chinese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Gang Liu).

Students may double count one course taken for the Chinese Studies minor that are also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Students with native or near-native proficiency in listening and speaking of the language prior to entering CMU should consult with the minor advisors for a different curriculum that may accelerate their completion of the requirement.

Course Requirements

1. Core Courses in Chinese Studies (36-39 units)

Complete four courses.

| | | |
|--------|--|----|
| 82-232 | Intermediate Chinese II (may be substituted by 82-235 Fables, Legends, and Stories from Ancient Chinese Civilization) | 12 |
| 82-235 | Fables, Legends and Stories from Ancient Chinese Civilization | 9 |
| 82-331 | Reading Into a New China I: Population, Youth, Marriage, & Housing | 9 |
| 82-332 | Reading Into a New China II: Transportation, Education, Pop Culture, & Health | 9 |
| 82-333 | Chinese Language and Culture ** | 9 |

*Students who place out of 82-232/82-235 must take a minimum of 9 additional units chosen from List A Electives.

2. Chinese Studies and Interdisciplinary Electives (18 units)

List A. Chinese Studies Electives

Complete two courses (18 units) from List A or one course (9 units) from List A and one (9 units) from List B.

| | | |
|------------|---|------|
| 82-334 | Structure of Chinese | 9 |
| 82-335 | Chinese Culture Through Legends and Folktales | 9 |
| 82-337 | Mandarin Chinese for Oral Communication I | 9 |
| 82-338 | Mandarin Chinese for Oral Communication II | 9 |
| 82-339 | Business Language & Culture in China I | 9 |
| 82-340 | Business Language & Culture in China II | 9 |
| 82-431 | China and the West | 9 |
| 82-432 | Chinese Popular Culture: A Game of Learning | 9 |
| 82-433 | Topics in Contemporary Culture of China * | 9 |
| 82-434 | Studies in Chinese Traditions * | 9 |
| 82-436 | Introduction to Classical Chinese * | 9 |
| 82-439 | Modern China Through Literature * | Var. |
| 82-440 | Studies in Chinese Literature & Culture * | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-531/532 | Special Topics in Chinese Studies * | Var. |

*Students may repeat these courses with new topics.

List B. Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and their minor advisor for the most up to date interdisciplinary electives appropriate for the Chinese Studies curriculum. Courses may be suggested to the minor advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|------------------------------|---|-------|
| Architecture | | Units |
| 48-551 | Ethics and Decision Making in Architecture | 9 |
| Art | | Units |
| 60-399 | Art History/Theory Independent Study | 9 |
| Business Administration | | Units |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| English | | Units |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-339 | Topics in Film and Media | 9 |
| 76-386 | Language & Culture | 9 |
| History | | Units |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-281 | Introduction to Religion | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| Modern Languages | | Units |
| 82-137 | Chinese Calligraphy: Culture and Skills | 9 |
| 82-230 | Cultural Topics in Chinese Studies | Var |
| 82-234 | Topics in Chinese History | 9 |
| 82-238 | Topics in Chinese Culture | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | Var. |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | Units |
| 80-180 | Nature of Language | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | Units |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |
| Social and Decision Sciences | | Units |
| 88-411 | Rise of the Asian Economies | 9 |

The Minor in French and Francophone Studies (54 units)

Faculty Advisor

Dr. Bonnie Youngs, Teaching Professor of French and Francophone Studies
(byoungs@cmu.edu)

Prerequisites

Elementary-level proficiency in French. This is equivalent to the completion of two 12-unit courses. Exemption from elementary or intermediate level

courses can be awarded based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. If students place out of the intermediate level, then additional courses at the 300 and 400 levels will be required to complete the minor. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Sébastien Dubreil, sdubreil@andrew.cmu.edu)

Students may double count one course taken for the French & Francophone Studies minor that are also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

Course Requirements

1. Complete two courses at the intermediate level.

| | | |
|--------|------------------------|---|
| 82-201 | Intermediate French I | 9 |
| 82-202 | Intermediate French II | 9 |

***Students placing out of the intermediate level must take two additional content courses at the 300 or 400 levels.**

2. Complete two courses at the 300 level and one course at the 400 level (27 units)

| | | |
|--------|--|------|
| 82-303 | French & Francophone Cultures * | 9 |
| 82-304 | French & Francophone Sociolinguistics * | 9 |
| 82-415 | Topics in French and Francophone Studies * | 9 |
| 82-416 | Topics in French and Francophone Studies * | 9 |
| 82-501 | Special Topics in French & Francophone Studies * | Var. |
| 82-502 | Special Topics in French & Francophone Studies * | Var. |
| 82-505 | Modern Languages Undergraduate Internship | Var. |

***Students may repeat these courses with new topics.**

3. Complete require course in Modern Languages (9 units)

| | | |
|--------|--|---|
| 82-283 | Language Diversity & Cultural Identity | 9 |
|--------|--|---|

The Minor in German Studies (54 units)

FACULTY ADVISOR

Dr. Gabriele Maier, Associate Teaching Professor of German Studies (eichgabi@andrew.cmu.edu) (eichgabi@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors. (Study abroad advisor - Dr. Gabriele Maier, eichgabi@andrew.cmu.edu)

Students may double count one course taken for the German Studies minor that are also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements, which has no limit.

1. Core Courses in German Studies (36 units)

| | | Units |
|--------|--|-------|
| 82-221 | Intermediate German I | 9 |
| 82-222 | Intermediate German II | 9 |
| 82-320 | Contemporary Society in Germany, Austria and Switzerland | 9 |
| 82-323 | Germany, Austria and Switzerland in the 20th Century | 9 |

2. German Studies & Interdisciplinary Electives (27 units)

| | | Units |
|------------|---|-------|
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-425/426 | Topics in German Literature and Culture * | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-521/522 | Special Topics in German Studies * | Var. |

| | | |
|------------------|--|-------|
| Architecture | | Units |
| 48-338 | European Cities in the XIX Century: Planning, Architecture, Preservation | 9 |
| 48-340 | Modern Architecture and Theory 1900-1945 | 9 |
| 48-350 | Postwar Modern Architecture and Theory | 9 |
| English | | Units |
| 76-239 | Introduction to Film Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-387 | Writing in the Disciplines | 6 |
| 76-483 | Research Methods in Technical & Professional Communication | 9 |
| History | | Units |
| 79-205 | 20th Century Europe | 9 |
| 79-257 | Germany and the Second World War | 9 |
| Modern Languages | | Units |
| 82-227 | Germany & the European Union | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | Var. |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-427 | Nazi and Resistance Culture ^(when taken entirely in English) | 9 |
| 82-428 | History of German Film ^(when taken entirely in English) | Var. |
| 82-480 | Translation Technologies | 9 |
| Music | | Units |
| 57-306 | World Music | 9 |
| Philosophy | | Units |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-180 | Nature of Language | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-256 | Modern Moral Philosophy | 9 |
| 80-275 | Metaphysics | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | Units |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

The Minor in Hispanic Studies (54 units)

Faculty Advisor:

Dr. Therese Tardio, Teaching Professor of Hispanic Studies (tardio@andrew.cmu.edu (tardio@andrew.cmu.edu))

Prerequisites:

Intermediate-level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors.

*Students may double count one course taken for the Hispanic Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements.

1. Core Courses in Hispanic Studies (27 units)

| | | Units |
|--------|------------------------------------|-------|
| 82-342 | Spain: Language and Culture | 9 |
| 82-343 | Latin America Language and Culture | 9 |
| 82-344 | U.S. Latinos: Language and Culture | 9 |

| | | | |
|--------|--|-------|---|
| 82-345 | Introduction to Hispanic Literary and Cultural Studies | Units | 9 |
|--------|--|-------|---|

2. Hispanic Studies and Interdisciplinary Electives (27 units)

| | | | |
|-------------------------------------|---|-------|---|
| 82-441 | Studies in Peninsular Literature and Culture * | Units | 9 |
| 82-443 | Spanish Reading and Translation Workshop | | 9 |
| 82-444 | The Structure of Spanish | | 6 |
| 82-451 | Studies in Latin American Literature and Culture | | 9 |
| 82-455/456 | Topics in Hispanic Studies * | | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. | |
| 82-541/542 | Special Topics in Hispanic Studies * | Var. | |
| Architecture | | Units | |
| 48-348 | Architectural History of Mexico & Guatemala | | 9 |
| English | | Units | |
| 76-385 | Introduction to Discourse Analysis | | 9 |
| 76-484 | Discourse Analysis | | 9 |
| 76-386 | Language & Culture | | 9 |
| 76-387 | Writing in the Disciplines | | 6 |
| History | | Units | |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | | 9 |
| 79-224 | Mayan America | | 9 |
| 79-237 | Comparative Slavery | | 9 |
| 79-276 | Beyond the Border | | 6 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | | 9 |
| Institute for Politics and Strategy | | Units | |
| 84-306 | Latin American Politics | | 9 |
| Modern Languages | | Units | |
| 82-245 | New Directions in Hispanic Studies | | 9 |
| 82-249 | Hispanic Language & Cultures for the Professions | | 9 |
| 82-247 | US Latinos Literature | | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | | 9 |
| 82-281 | Contextual Thinking | | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. | |
| 82-283 | Language Diversity & Cultural Identity | | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | | 9 |
| 82-388 | Topics in Second Language Acquisition | | 9 |
| 82-480 | Translation Technologies | | 9 |
| Music | | Units | |
| 57-306 | World Music | | 9 |
| Philosophy | | Units | |
| 80-180 | Nature of Language | | 9 |
| 80-280 | Linguistic Analysis | | 9 |
| 80-285 | Natural Language Syntax | | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | | 9 |
| 80-380 | Philosophy of Language | | 9 |
| 80-381 | Meaning in Language | | 9 |
| Psychology | | Units | |
| 85-375 | Crosscultural Psychology | | 9 |
| 85-421 | Language and Thought | | 9 |

Students in the Immersive Technologies in Arts & Culture (<https://ideate.cmu.edu/undergraduate-programs/immersive-technologies-in-arts-culture/>) minor will be hybrid technologists, media-makers, and storytellers who can create mediated experiences at the intersection of technology, design, and the humanities. They will be equipped with the social consciousness, global awareness, and cross-cultural skills needed to forge positive new paths for immersive media going into the future.

Students in the minor will learn to construct and deconstruct immersive and augmented experiences with respect to the cultural, socio-emotional, and embodied aspects of human experience. They will develop the technical know-how and creative production skills to collaboratively author original

narratives and prototype spatially mediated experiences. In the making of augmented and immersive media, students will explore the narrative possibilities and technical affordances of the genre while attending to the aesthetic considerations, humanistic concerns, and design conventions defining this emerging mode of cultural production.

One IDEATE Portal Course (minimum of 9 units):

| | | |
|--------|--|---|
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
|--------|--|---|

One Intercultural Focus Course (minimum of 9 units):

| | | |
|--------|--|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |

One Computing Course (minimum of 9 units):

| | | |
|--------|--|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

IDEATe Immersive Technologies Courses (minimum of 27 units)*:

| | | |
|-----------|--|----|
| 15-365 | Experimental Animation | 12 |
| or 60-422 | Advanced ETB: Experimental Animation | |
| 15-463 | Computational Photography | 12 |
| 53-353 | Understanding Game Engines | 9 |
| 53-373 | Dynamic Motion and Game Experience | 12 |
| 53-376 | 360 Story and Sound | 12 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 53-558 | Reality Computing Studio | 12 |
| 54-397 | Sound Design For Interactive Environments | 9 |
| 54-399 | Decoding Media | 9 |
| 60-413 | Advanced ETB: Real-Time Animation | 10 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |

*Additional courses are available. Please check IDEATe Courses (<https://ideate.cmu.edu/courses/current-courses.html>) for the options for the current and upcoming semester.

Double-counting: Students may double-count up to two of their IDEATe minor courses for other requirements.

Advisor

Ryan McKelvey (rmckelve@andrew.cmu.edu)

Immersive and spatial media encompass a suite of emerging production and embodied viewing technologies that offer innovative possibilities in the arts, entertainment, science, industry, and countless other domains. Technologies seeded 50 years ago are now entering commercial, political and cultural realms; and the potential for augmented and immersive experiences to further disrupt our current media ecosystem is tremendous. As immersive experiences and augmented realities increasingly feature in work and leisure, young innovators are needed who can blend technological skills with creative imagination and critical humanistic practice.

Students in the Immersive Technologies in Arts & Culture minor will be hybrid technologists, media-makers, and storytellers who can create mediated experiences at the intersection of technology, design, and the humanities. They will be equipped with the social consciousness, global awareness, and cross-cultural skills needed to forge positive new paths for immersive media going into the future.

Students in the minor will learn to construct and deconstruct immersive and augmented experiences with respect to the cultural, socio-emotional, and embodied aspects of human experience. They will develop the technical know-how and creative production skills to collaboratively author original narratives and prototype spatially mediated experiences. In the making of augmented and immersive media, students will explore the narrative possibilities and technical affordances of the genre while attending to the

aesthetic considerations, humanistic concerns, and design conventions defining this emerging mode of cultural production.

Double-counting: Students may double-count up to two of their IDEATe minor courses for other requirements. Please discuss double-counting with the IDEATe advisor.

Course Requirements

1. Complete one IDEATe Portal Course

| | | |
|--------|--|---|
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
|--------|--|---|

2. Complete at least one Interculture Focus Course (minimum 9 units)

| | | |
|--------|--|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |

3. Complete on Computing Course (minimum of 9 units)

| | | |
|--------|--|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

4. Complete three Immersive Technologies Courses (minimum of 27 units)

| | | |
|--------|--|----|
| 15-365 | Experimental Animation | 12 |
| 15-463 | Computational Photography | 12 |
| 48-339 | IDEATe: Making Things Interactive | 12 |
| 53-353 | Understanding Game Engines | 9 |
| 53-373 | Dynamic Motion and Game Experience | 12 |
| 53-376 | 360 Story and Sound | 12 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 53-558 | Reality Computing Studio | 12 |
| 54-397 | Sound Design For Interactive Environments | 9 |
| 54-399 | Decoding Media | 9 |
| 60-413 | Advanced ETB: Real-Time Animation | 10 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |

***Additional courses as available. Please consult the IDEATe Courses for the current and upcoming semesters.**

The Minor in Japanese Studies (54-57 units)

Faculty Advisor:

Dr. Yasufumi Iwasaki, Associate Teaching Professor of Japanese
(yiwasaki@andrew.cmu.edu)

Prerequisites

Intermediate-level proficiency in the Japanese language. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level), or placement or exemption based on Advanced Placement, Cambridge GCE Advanced level, International Baccalaureate or CMU internal placement test scores. In all cases, progress will be accelerated by study abroad, which is highly recommended for all minors.

*Students may double count one courses taken for the Hispanic Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include double-counting with General Education requirements.

1. Core Courses in Japanese Studies (36-39 units*)

| | | |
|--------|---|----|
| 82-272 | Intermediate Japanese II * | 12 |
| 82-273 | Introduction to Japanese Language and Culture | 9 |
| 82-371 | Changes in Japan 1: Food and Work Cultures | 9 |
| 82-372 | Advanced Japanese II | 9 |

82-272

2. Japanese Studies and Interdisciplinary Electives (18 units)

| | | |
|--------|--|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |

3. Complete on Computing Course (minimum of 9 units)

| | | |
|------------|---|------|
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-473/474 | Topics in Japanese Studies * | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-571/572 | Special Topics in Japanese Studies * | Var. |

English

| | | |
|--------|------------------------------|---|
| 76-239 | Introduction to Film Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-387 | Writing in the Disciplines | 6 |

History

| | | |
|--------|---|---|
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-275 | Introduction to Global Studies | 9 |

Modern Languages

| | | |
|--------|---|------|
| 82-234 | Topics in Chinese History | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-279 | Anime - Visual Interplay between Japan and the World | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | Var. |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Music

| | | |
|--------|-------------|---|
| 57-306 | World Music | 9 |
|--------|-------------|---|

Philosophy

| | | |
|--------|------------------------|---|
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |

Psychology

| | | |
|--------|--------------------------|---|
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

The Minor in Russian Studies (54-57 units)

Faculty Advisor

Dr. Tatyana Gershkovich, Associate Professor of Russian Studies

The minor in Russian Studies is jointly administered by the Departments of History and Modern Languages. Students are required to fulfill requirements in history and in language and culture.

Prerequisites

The minor in Russian Studies is an interdepartmental, interdisciplinary minor jointly administered by the Departments of History and Modern Languages. Students are asked to fulfill requirements in history and in language and culture. Additionally, students are strongly encouraged to study abroad in Russia or other parts of the Russian-speaking world. Not only does study abroad offer students a memorable and formative experience of cultural immersion, it also helps them advance to their highest possible levels of linguistic and cultural competence by the time they graduate.

Students may double count a maximum of one course taken for the Russian Studies minor that is also being used to fulfill the requirements of other majors, minors, and programs. This does not include requirements for General Education requirements.

Course Requirements

1. Core Courses in Russian (33-36 units)

Complete three language courses.

| | | |
|--------|------------------------|----|
| 82-191 | Elementary Russian I | 12 |
| 82-192 | Elementary Russian II | 12 |
| 82-291 | Intermediate Russian I | 12 |

* N.B. Students with native or near-native proficiency in Russian or with prior study at the elementary or intermediate level may begin language study at a higher level, based on consultation with the major advisor. Students placing higher will still need to complete a minimum of 33 units, though they may do this by adding 3-unit language enrichment credits to content-based courses.

2. Core Courses in Modern Languages (12 units)

Complete one course

| | | |
|--------|-----------------------------------|------|
| 82-292 | Intermediate Russian II | 12 |
| 82-294 | 19th Century Russian Masterpieces | Var. |
| 82-295 | 20th Century Russian Masterpieces | Var. |

These 9 unit content-based courses are taught in English plus 3 units of content-based study in Russian.

3. Core Courses in History (9 units)

Complete one course

| | | |
|--------|---|---|
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |

4. Highly Recommended Electives for Minors

In addition to fulfilling the course requirements, Russian minors are encouraged to take an elective course from the list below. Courses not listed may be suggested to the major advisor for approval as a substitute. Note that not all courses are offered each semester. Courses marked by * are offered in English but may be taken with 3 units of content-based study in Russian, subject to individual faculty approval.

| | | Units |
|-------------------------|---|-------|
| History | | |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-322 | Stalin and the Great Terror | 9 |
| Modern Languages | | |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | Var. |
| 82-391 | Advanced Russian I - Berlin, Paris, New York, Harbin | 9 |
| 82-392 | Advanced Russian II: Great Short Works | 9 |
| 82-394 | Russian for Heritage Speakers: Babushka's Russia & Beyond | 9 |
| 82-397 | Radicals, Heretics, Hackers: Russian Outlaws in History, Literature, and Film | Var. |
| 82-492 | The Historical Imagination in Nineteenth-Century Russian Literature | Var. |

* Students may repeat these course with new topics.

Study Abroad

A semester or year of study abroad is strongly recommended. Consult with your advisor and the Office of International Education (OIE) about possible options. Students are encouraged to spend a semester or summer in Russia via an approved exchange program. Many exchange programs offer instruction in Russian language, history, literature, and culture, in internationally recognized universities. They also offer travel to ancient sites and cities, visits to museums, palaces, exhibitions, and monuments, and the opportunity to live with a Russian host family. Scholarship opportunities are available.

Faculty

KHALED AL MASAEEED, Associate Professor of Arabic Studies and Second Language Acquisition - Ph.D., The University of Arizona; Carnegie Mellon, 2016-

STEPHEN BROCKMANN, Professor of German with courtesy appointments in English and History - Ph.D., University of Wisconsin Madison; Carnegie Mellon, 1993-

KATHARINE BURNS, Assistant Professor of Second Language Acquisition and Hispanic Studies - Ph.D., University of Arizona; Carnegie Mellon, 2016-

CHARLENE CASTELLANO, Teaching Professor of Russian Emeritus - Ph.D., Cornell University; Carnegie Mellon, 1990-

SÉBASTIEN DUBREIL, Teaching Professor of French & Francophone Studies, Second Language Acquisition and Technology Enhanced Learning - Ph.D., Emory University; Carnegie Mellon, 2016-

KENYA C. DWORKIN Y MENDEZ, Associate Professor of Hispanic Studies with courtesy appointments in English and History - Ph.D., University of California, Berkeley; Carnegie Mellon, 1993-

JOSÉ ESTRADA, Assistant Teaching Professor of Hispanic Studies - Ph.D., University of Chicago; Carnegie Mellon, 2019-

BARBARA FREED, Professor Emeritus of French & Francophone Studies and Second Language Acquisition - Ph.D., University of Pennsylvania; Carnegie Mellon, 1990-

KIYONO FUJINAGA-GORDON, Assistant Teaching Professor of Japanese Studies - Ph.D., University at Buffalo, SUNY; Carnegie Mellon, 2023-

TATYANA GERSHKOVICH, Associate Professor of Russian Studies - Ph.D., Harvard University; Carnegie Mellon, 2016-

FELIPE GOMEZ, Teaching Professor of Hispanic Studies - Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2006-

CHRISTIAN HALLSTEIN, Teaching Professor Emeritus of German - Ph.D., Pennsylvania State University; Carnegie Mellon, 1979-

ERIK HELIN, Special Lecturer, Carnegie Mellon - Qatar - MA , Eastern Michigan; Carnegie Mellon, 2006-

PAUL HOPPER, Paul Mellon Distinguished Professor Emeritus of the Humanities, Rhetoric and Linguistics with a courtesy appointment in Modern Languages - Ph.D., University of Texas; Carnegie Mellon, 1990-

ZEINAB IBRAHIM, Associate Teaching Professor, Carnegie Mellon - Qatar - Ph.D., Georgetown University; Carnegie Mellon, 2009-

YASUFUMI IWASAKI, Associate Teaching Professor of Japanese - Ph.D., University of Illinois; Carnegie Mellon, 2005-

BARBARA JOHNSTONE, Professor Emeritus of Rhetoric and Linguistics with a courtesy appointment in Modern Languages - Ph.D., University of Michigan; Carnegie Mellon, 1997-

CHRISTOPHER M. JONES, Teaching Professor Emeritus of French & Francophone Studies and Director of Modern Language Resource Center - Ph.D., University of Massachusetts, Amherst; Carnegie Mellon, 1993-

KEIKO KODA, Professor of Japanese and Second Language Acquisition and Director of Graduate Studies - Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 1995-

ANNE LAMBRIGHT, Department Head and Professor of Hispanic Studies - Ph.D., University of Texas; Carnegie Mellon, 2020-

CHENG LI, Assistant Professor of Chinese Studies - Ph.D., Yale University; Carnegie Mellon, 2022-

GANG LIU, Teaching Professor of Chinese Studies - Ph.D., University of Michigan; Carnegie Mellon, 2010-

CHRISTOPHER LOWY, Assistant Professor of Japanese Studies - Ph.D., University of Washington;

BRIAN MACWHINNEY, Professor of Psychology with a courtesy appointment in Modern Languages – Ph.D., University of California, Berkeley; Carnegie Mellon, 1981-

GABRIELE MAIER, Teaching Professor of German – Ph.D., University of Washington; Carnegie Mellon, 2008-

MAME-FATOU NIANG, Associate Professor of French & Francophone Studies – Ph.D., Louisiana State University; Carnegie Mellon, 2012-

DAVID PARKER, Assistant Professor of Russian Studies – Ph.D., UC-Berkeley; Carnegie Mellon, 2021-

SUSAN G. POLANSKY, Teaching Professor Emeritus of Hispanic Studies – Ph.D., Boston College; Carnegie Mellon, 1986-

GIOVANNI PUPPO, Instructor of Italian – Ph.D., University of Rome; Carnegie Mellon, 1975-

JURIS SILENIEKS, Professor Emeritus of French – Ph.D., University of Nebraska; Carnegie Mellon, 1960-

CANDACE SKIBBA, Associate Teaching Professor of Hispanic Studies – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2006-

DONALD SUTTON, Professor Emeritus of History with a courtesy appointment in Modern Languages – Ph.D., Cambridge University; Carnegie Mellon, 1969-

THERESE TARDIO, Teaching Professor of Hispanic Studies – Ph.D., University of Pittsburgh; Carnegie Mellon, 2001-

G. RICHARD TUCKER, Paul Mellon University Professor Emeritus of Applied Linguistics with a courtesy appointment in Psychology – Ph.D., McGill University; Carnegie Mellon, 1992-

JAN VAIRO, Senior Lecturer – M.A., University of Pittsburgh; Carnegie Mellon, 1992-

REMI (ADAM) VAN COMPERNOLLE, Associate Professor of French & Francophone Studies & Second Language Acquisition – Ph.D., Penn State; Carnegie Mellon, 2012-

MICHAEL J. WEST, Emeritus Teaching Professor of French & Francophone Studies – Ph.D., University of California-Santa Barbara; Carnegie Mellon, 1989-

DANIELLE WETZEL, Teaching Professor and Director of First Year Writing with a courtesy appointment in Modern Languages – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006-

SETH WIENER, Associate Professor of Second Language Acquisition and Chinese – Ph.D., Ohio State University; Carnegie Mellon, 2015-

SUE-MEI WU, Teaching Professor of Chinese Studies – Ph.D., Ohio State University; Carnegie Mellon, 2000-

TIANXUE YAO, Senior Lecturer – M.A., Carnegie Mellon University, M.A., JiLin University; Carnegie Mellon, 1996-

YOSHIHIRO YASUHARA, Associate Teaching Professor of Japanese Studies – Ph.D., Pennsylvania State University; Carnegie Mellon, 2010-

BONNIE L. YOUNGS, Teaching Professor of French & Francophone Studies and Director of Undergraduate Studies – Ph.D., University of Pennsylvania; Carnegie Mellon, 1993-

YUEMING YU, Teaching Professor Emeritus of Chinese Studies – Ed.D., University of Pittsburgh; Carnegie Mellon, 1992-

Department of Modern Languages Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

82-101 Elementary French I

Fall and Spring: 12 units

This course is for students with no prior experience in French. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken French, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of French and francophone cultures through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in French must take the placement exam.

82-102 Elementary French II

Fall and Spring: 12 units

This course is designed for students who have taken first-semester French at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken French, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of French and francophone cultures through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in French must take the placement exam.

Prerequisites: 82-101 or 82-103

82-103 Elementary French I Online

Fall and Spring: 12 units

This course is designed for students with no prior experience with French and who need a more flexible approach to language learning than that offered in a standard classroom course. Beginning language learners will develop communicative competence in the four basic skills of listening, speaking, reading and writing. Basic vocabulary and sentence structures for use in essential daily-life situations, as well as cultural information, are taught through the course materials and assignments. Materials are web-based, with extensive use of Internet technologies for listening, reading, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in French must take the placement exam.

82-104 Elementary French II Online

Fall and Spring: 12 units

This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. Students will learn more useful and complex expressions and sentence structures necessary for use in everyday life. Students will continue building their skills in listening, speaking, reading, and writing for everyday communication. Additionally, course materials and assignments are designed to improve students' understanding of French and francophone cultures and societies. Materials are web-based with extensive use of Internet technologies for listening, reading, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in French must take the placement exam.

Prerequisites: 82-101 or 82-103

82-109 Introduction to Arabic I

Intermittent: 9 units

This course is the first part of a two-semester sequence (82-109, 82-110) for students with no background in Arabic. It covers the first half of 82-111 in one semester through introducing learners to Modern Standard Arabic (MSA) in its written and spoken forms to achieve communicative competence at the elementary level in all language skills (listening, speaking, reading, and writing). To this end the course follows a proficiency-oriented approach to language teaching. In addition to MSA, the course introduces students to one of the popular spoken dialects in the Arab world such as Egyptian, Levantine, or Moroccan (depending upon the instructor's background/expertise). Students will also study various cultural aspects of the Arab world through written, audio-visual and online-based materials. Regular homework, quizzes, tests, presentations, and class participation are required (three in-class hours per week plus six hours of required homework). Students who intend to do a minor in Arabic Studies should consult with the Arabic minor advisor before deciding on 82-109 or 82-111.

82-110 Introduction to Arabic II

Intermittent: 9 units

TBA

Prerequisite: 82-109

82-111 Elementary Arabic I

Fall: 12 units

This course introduces learners to Modern Standard Arabic (MSA) in its written and spoken forms to achieve communicative competence at the elementary level in all language skills (listening, speaking, reading, and writing). To this end the course follows a proficiency-oriented approach to language teaching. In addition to MSA, the course introduces students to one of the popular spoken dialects in the Arab world such as Egyptian, Levantine, or Moroccan (depending upon the instructor's background/expertise). Students will also study various cultural aspects of the Arab world through written, audio-visual and online-based materials. Students with prior knowledge of Arabic must take the placement exam.

82-112 Elementary Arabic II

Spring: 12 units

This course builds on Elementary Arabic I to continue introducing students to Modern Standard Arabic (MSA) to achieve communicative competence at the Novice-High/Intermediate-Low level in all language skills (listening, speaking, reading, and writing). To this end, the course follows a proficiency-oriented approach to language teaching. In addition to MSA, the course continues to introduce students to one of the popular spoken dialects in the Arab world such as Egyptian, Levantine, or Moroccan (depending upon the instructor's background/expertise). Students will continue to explore various cultural aspects of the Arab world through written, audio-visual and online materials.

Prerequisite: 82-111

82-114 Arabic for Global Exchange Online

Fall and Spring: 6 units

This class focuses primarily on learning about Arab culture with a minor focus on learning functional Arabic language. The course introduces learners to basic concepts and information to facilitate entry and engagement in an Arabic-speaking environment, and utilizes instructional materials to introduce basic cultural knowledge and survival language. This is a mini-course for individuals with no proficiency or extremely limited knowledge of Arabic language and Arab culture. Each of the six lessons in the course includes texts and activities to promote acquisition of cultural content in English as well as basic introductory exposure to the Arabic language. Synchronous individual or small group online meetings to discuss course content will be arranged during the first week of the course. All course materials are hosted by the Online Learning Initiative, with guidance provided by the instructor via Canvas. Class evaluation is based on contributions to online discussion forums, synchronous online meetings in English with the instructor, synchronous online meetings in Arabic with a speaking assistant, and a final project.

82-115 Beginning Arabic for Oral Communication

Intermittent: 6 units

ARABIC FOR ORAL COMMUNICATION is designed for students who desire to learn how to orally communicate in Arabic or who have taken Arabic for Global Exchange. This course does not teach how to read or write Arabic. It offers students the opportunity to engage in speaking and listening activities and complete a variety of related oral practice assignments in and outside of class, using a spoken Arabic that would be widely understood anywhere in the Arab World. The conversation topics will be greetings, self-introduction, hobbies, proper terms of address in casual and professional settings, and describing feelings and places.

82-116 Arabic Cultural Issues Past & Present

Fall and Spring: 9 units

This course is offered only at Carnegie Mellon's campus in Qatar. This course is intended for students who wish to master speaking in Modern Standard Arabic (MSA). This is done through reading articles on customs and traditions of the Arabs and discussing them thoroughly in class using MSA. Since this is an elementary level course, it is to help students switch from their dialect to speaking MSA. Through the reading of complex articles and texts on customs and traditions of Arabs and discussing them thoroughly in class using Modern Standard Arabic (MSA), students will engage in academic conversations with the goals of a developing a deeper understanding of Arab cultures and a facility to use MSA at an academic level. An elementary level course, this course is designed for students who wish to improve their proficiency in speaking and reading MSA as an alternative to their dialect.

82-117 Arabic Conversation & Dialect I

Fall and Spring: 6 units

This course introduces students to a particular dialect of Arabic and to the culture of the region where the dialect is spoken. The dialect of the course will vary based on the instructor's background/expertise (for example, Levantine, Egyptian, Moroccan, etc.). This class adopts a proficiency-based approach and the content of the course will be organized around specific themes such as greetings, introductions, directions, family, food, etc. Students will be required to engage actively in speaking activities and complete a variety of related oral practice assignments outside of class. Because of the significant contribution of technology in facilitating and empowering language learning and language teaching, a substantial part of communication, activities, and assignments will be done via programs such as Aswaat Arabiyya, BYKI, Film clips, Skype, Youtube, etc. Please contact the department for specific information on the upcoming semester's course content.

82-118 Arabic Conversation & Dialect II

Fall and Spring: 6 units

This course continues students' exploration of the same regional dialect and culture taught in Arabic Conversation and Dialect I for that particular semester. The content of the course will be organized around specific themes that build on previously introduced topics (e.g., daily schedule, weddings, traveling, hobbies, etc.). Students will be required to engage actively in speaking activities and complete a variety of related oral practice assignments outside of class. Because of the significant contribution of technology in facilitating and empowering language learning and language teaching, a substantial part of communication, activities, and assignments will be done via programs such as Aswaat Arabiyya, BYKI, Film clips, Skype, Youtube, etc. Please contact the department for specific information on the upcoming semester's course content.

Prerequisite: 82-117 Min. grade C

82-119 Arabic Calligraphy Culture & Skills

Fall and Spring: 9 units

This course introduces its participants to historical and cultural contexts and various techniques used to produce Arabic calligraphy works. No previous knowledge of the Arabic script or language is necessary. At the end of the course, participants will demonstrate familiarity and comfort with key movements in the history and art of Arabic calligraphy, and read simple alphabet constructions or words in a variety of styles. Participants will apply proper techniques to producing calligraphy in two of the most commonly used styles, Naskh and Riq'ah, as well as experiment with some modern script styles. The class will use lecture discussions, audio-visual media, projects, guest speakers, and field trips as occasions arise.

82-121 Elementary German I

Fall and Spring: 12 units

This course is for students with no prior experience in German. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken German, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of German-speaking cultures through class activities. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). A student with prior experience in German must take the placement exam.

82-122 Elementary German II

Fall and Spring: 12 units

This course is designed for students who have taken first-semester German at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken German, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of German cultures through class activities. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). A student with prior experience in German must take the placement exam. Prerequisites: 82-123 or 82-121

82-123 Directed Language Study: Elementary German I or II

Fall and Spring: 12 units

This course is a directed, instructor-supervised version of the courses 82-121 or 82-122. It is recommended for (1) students who are strongly motivated and have the time, self-discipline, and desire to work independently, (2) students whose schedule precludes enrollment in the regular elementary course, and/or (3) students who have had previous German study but are not prepared to take 82-122. This course develops the fundamental language skills as outlined in the descriptions of 82-121 and 82-122, and students complete the same work as for those courses. Written work is turned in for correction and tests covering each unit of material will be taken according to a schedule determined by the instructor. The instructor will be available during office hours or by appointment for individual consultations and testing. Students are permitted to take only one semester of 82-123.

82-130 Navigating Chinese Culture: Intro to the Three Kingdoms

Intermittent: 9 units

This course introduces students to the basics of Chinese culture in order to assist them to better understand and appreciate traditional Chinese humanistic ideas, thoughts and value systems, with a focus on the Confucian point of view. Through the study of the classic novel, *The Three Kingdoms*, the most valued virtues within Chinese culture and society - loyalty, filial piety, benevolence and righteousness - are presented and discussed. Different aspects of the daily life culture will be introduced as well. Supplementary readings, video clips as well as video games will be used to provide students with a deeper insight, observation and motivation to explore more issues related to Chinese culture, history and philosophy. Assessment will be based on short essays, group projects and individual presentations. Some basic Chinese language instruction will be included to give students a taste of the Chinese language. After taking this course, students will - develop a basic understanding of the essence of Chinese culture - build an awareness of cultural differences between different countries - understand some basic characteristics of Chinese language This course is conducted in English; no prior knowledge of the Chinese culture is required.

82-131 Elementary Chinese I

Fall and Spring: 12 units

This course is for students with no prior experience in Chinese. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken Chinese, develop reading and listening skills through various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of Chinese cultures through class and extracurricular activities. Regular homework, quizzes, tests, and participation in class are mandatory (four in-class hours per week). Students will learn the phonetic transcriptions of Chinese (Pinyin) for speaking and listening as well as Chinese characters for reading and writing. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Chinese must take the placement exam.

82-132 Elementary Chinese II

Fall and Spring: 12 units

This course is designed for students who have taken first-semester Chinese at Carnegie Mellon or its equivalent by placement. Students will continue developing contextually appropriate interpersonal communication skills in both written and spoken Chinese, developing reading and listening skills through various media, and working toward a deeper understanding of Chinese culture. Work for this course will include the introduction and use of more complicated sentence structures, grammar, and expressions. Students are also encouraged to communicate in longer sentences and write short paragraphs and essays in Chinese. Regular homework, quizzes, tests, and participation in class are mandatory (four in-class hours per week). Students will continue to learn the phonetic transcriptions of Chinese (Pinyin) for speaking and listening as well as Chinese characters for reading and writing. The elementary level is designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Chinese must take the placement exam.

Prerequisites: 82-131 or 82-133

82-133 Elementary Chinese Online I

Fall: 12 units

This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. It is a Chinese language course designed to help beginners develop communicative competence in the four basic skills of listening, speaking, reading and writing the Chinese language. Basic vocabulary and sentence structures for use in essential daily-life situations, as well as cultural information, are taught through the materials and assignments. Materials are web-based, with extensive use of Internet technologies for research, writing and communication. There is a required weekly class meeting for training and for group activities, and weekly individual meetings with a tutor or the instructor for conversation and practice.

82-134 Elementary Chinese Online II

Spring: 12 units

This course is the continuation of 82-133, Elementary Chinese I Online. Students will continue learning more useful and complex expressions and sentence structures necessary for use in everyday life. Students will continue building their skills in listening, speaking, reading, and writing for everyday communication, and their understanding of Chinese culture and society. There is a required weekly class meeting for training and for group activities, and weekly individual meetings with a tutor for conversation and practice.

Prerequisites: 82-133 or 82-131

82-135 Cultural Roots: Chinese Language & Culture for Heritage Learners

Fall and Spring: 9 units

Different from "Elementary Chinese I", this 9-unit Chinese language course is geared towards the needs of Chinese heritage students who have basic prior exposure to Chinese and with the intention to improve their Chinese literacy skills and Chinese culture awareness. This course helps students to better develop their daily reading and writing competence through a balanced and systematic training. By adopting the multimedia teaching materials, including language textbooks and culture-oriented audio and video English materials, this course will have an equal emphasis on both Chinese language and Chinese American historical events and culture. This course is intended to promote the students' cross-cultural knowledge and identity awareness. Students will be assessed in terms of their Chinese listening, speaking, reading and writing skills at the elementary level as well as their understanding of the Chinese American history and culture corresponding to their background. This course is taught in both Chinese and English.

82-137 Chinese Calligraphy: Culture and Skills

Fall and Spring: 9 units

Chinese calligraphy is a crucial part of Chinese culture and world art. It is also a clear manifestation of Chinese philosophy that has influenced Chinese people for several thousand years. This introductory course on Chinese calligraphy provides students with basic knowledge of Chinese calligraphy and how it mirrors Chinese history, culture, and philosophy. It will also introduce the fundamental characteristics of the Chinese writing system, its cultural content, and principles of formation as well as the skills used in Chinese calligraphy. At the end of the course, students will have a good understanding of Chinese characters and their cultural and philosophical background but also be able to appreciate the art and beauty in Chinese calligraphy. Classes include lectures, discussions, hands-on practice, and projects.

82-138 Comparative China: Perceptions Through Youtube & TikTok

Fall and Spring: 9 units

F2022: The world knows China through different media: books, newspapers, television, films, and social media. While these media provide unique and valuable windows for us to look into Chinese society and culture, they sometimes also confine our perspectives, or even distort our visions, because of the limitations of the platforms, the motives and standpoints of the media creators, and the methods or channels used for communication. Because of this, how to critically evaluate the images and information presented to us by the media and how to analyze them from a cross-cultural perspective, become the prerequisites for all our discussions and understanding of China and its role in the world nowadays. This course focuses specifically on the "images" of China and Chinese society as presented through the emerging social media such as YouTube and TikTok. In addition to helping student gain better knowledge of Chinese society and culture, the course also invites students to examine and discuss the perspectives behind these media materials, the cultural agenda of their creation, the strategies and methods used in their dissemination, as well as the impact of these factors on the audience's perceptions of China.

82-139 Topics in Chinese Language, Culture and Society

Spring: 9 units

F23: What are the meanings behind the lyrics, poses, and moves in Chinese local operas, Chinese classical dances, martial arts and pop songs? How are they connected to Chinese social, religious and cultural beliefs? Do you want to try the moves and poses of opera performers and Chinese dancers? Do you want to manipulate Chinese puppets like a puppet master? Do you want to learn Taichi, Chinese martial arts, games and fitness dance to improve your mental and physical health? Are you interested in tasting some Chinese food, doing some Chinese cooking and learning about Chinese food culture, table manners and etiquette? Would you like to learn Chinese knots, calligraphy and other Chinese crafts? Do you want to apply your learning to community engagements to share your learning and have a positive impact? 82-139: Chinese Learning Through Cultural Practices and Community Engagement is where you can immerse yourself in these cultural learning activities through discussions, group collaborations, and hands-on practice. This course aims to help students understand Chinese society and culture through instruction as well as experiential learning. The course is structured to have three major components: (1) group learning and discussion (2) immersive hands-on experiences (3) collaborative activities, projects and community engagements. Class activities will include showcases of media, digital and printed materials, lectures and discussion, guest speakers, hands-on practice, students' oral reports, and presentation of final term projects showcased in community engagements. The class is in English

82-141 Elementary Spanish I

Fall and Spring: 12 units

Elementary Spanish I is for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns, frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. This course also provides extracurricular opportunities to interact with members of the Spanish-speaking community. Four hours of in-class instruction per week are required. A student with prior experience in Spanish must take the placement exam.

82-142 Elementary Spanish II

Fall and Spring: 12 units

Elementary Spanish II is the second class for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns, frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. This course also provides extracurricular opportunities to interact with members of the Spanish-speaking community. Four hours of in-class instruction per week are required. A student with prior experience in Spanish must take the placement exam.

Prerequisites: 82-141 or 82-143

82-143 Elementary Spanish I Online

Fall: 12 units

Elementary Spanish Online I is for beginning students, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns. This course is designed for students with no previous knowledge of Spanish and who need a more flexible approach to language learning than that offered in a standard classroom course. All materials are Web-based, with extensive use of Internet technologies for research, writing, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. Students who have taken Spanish before are required to take the placement exam.

82-144 Elementary Spanish II Online

Spring: 12 units

Elementary Spanish Online II is the second part of a two-course sequence, emphasizing the development of communicative language and cultural competence. Students will work towards improving their writing, reading, listening and speaking abilities in Spanish, such that they become comfortable working with a variety of topics from Spanish-speaking cultural areas. Students will develop basic interactional and routine public communication patterns. This course is designed for students who need a more flexible approach to language learning than that offered in a standard classroom course. All materials are Web-based, with extensive use of Internet technologies for research, writing, and communication. During regular semesters, this course is offered in a hybrid mode requiring one 80-minute class per week in addition to weekly 20-minute individual meetings with the instructor or a peer speaking assistant. There is a materials fee for taking this course which is paid by credit card on first log-in to the course website. A student with prior experience in Spanish must take the placement exam. Instructions for the placement exam are available in Baker Hall 160.

Prerequisites: 82-143 or 82-141

82-151 Elementary Korean I

Fall: 12 units

This course is for students with no prior experience in Korean. It emphasizes the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Korean society through the use of authentic materials (e.g., Korean dramas, audio and video materials elicited from L2 Korean learners' conversations). Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). Necessary assistance to succeed in the class will be provided through rounds of feedback, in/out-of-class rich practices, and resources for individual practices. The elementary level is also designed to help students learn to reflect and draw upon strategies that can be used to achieve learning goals. A student with prior experience in Korean must take the placement exam.

82-161 Elementary Italian I

Fall: 12 units

This course is for students with no prior experience in Italian. Using a proficiency-oriented approach, students will develop contextually appropriate interpersonal communication skills in both written and spoken Italian, develop reading and listening skills through the use of various media, understand fundamental grammar, acquire vocabulary, and gain a basic understanding of Italian culture through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Italian must take the placement exam.

82-162 Elementary Italian II

Spring: 12 units

This course is designed for students who have taken first-semester Italian at Carnegie Mellon or learned its equivalent as determined by placement. Using a proficiency-oriented approach, students will expand contextually appropriate interpersonal communication skills in both written and spoken Italian, continue to develop reading and listening skills through the use of various media, review previously learned and practice new grammar and vocabulary, and gain a further understanding of Italian culture through class activities. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Italian must contact the Department of Modern Languages for placement.

Prerequisites: 82-163 or 82-161

82-163 Directed Language Study: Elementary Italian I or II

Fall and Spring: 12 units

A self-paced version of first or second semester Elementary Italian, this course is for highly motivated students capable of working independently. The coursework includes weekly classes, aural practice using online materials, periodic assessments, and individual meetings with the instructor. Students are permitted to take only one semester of 82-163. A student with prior experience in Italian must take the placement exam.

82-171 Elementary Japanese I

Fall and Spring: 12 units

This course is the first part of a two-semester course sequence (82-171, 82-172) for students with no prior experience in Japanese. It emphasizes the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Japanese must take the placement exam.

82-172 Elementary Japanese II

Fall and Spring: 12 units

This course is a sequel to Elementary Japanese I (82-171) and continues to further the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (four in-class hours per week). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. A student with prior experience in Japanese must take the placement exam.

Prerequisites: 82-174 or 82-171

82-173 Introduction to Japanese I

Fall and Spring: 9 units

This course is the first part of a two-semester sequence (82-173, 82-174) for students with no background in Japanese. Since it covers the first half of 82-171 in one semester, it is suitable for those students who need sufficient practice time both in and outside of class to begin their study of Japanese. It emphasizes the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. Regular homework, quizzes, tests, presentations, and class participation are mandatory (three in-class hours per week plus six hours of required homework). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Students who intend to minor or major in Japanese should consult with their Japanese minor or major advisor before deciding on 82-171 or 82-173. Students with prior knowledge of Japanese must take the placement exam.

82-174 Introduction to Japanese II

Fall and Spring: 9 units

This course is a sequel to Introduction to Japanese I (82-173) for students with no background in Japanese. Since the course covers the second half of the 82-171 in one semester, it is suitable for those students who need lots of practice time both in and outside class. It continues to further the development of communicative language proficiency through oral practice, aural comprehension, reading, writing, and the study of cultural aspects of Japanese society. The elementary level is also designed to help students learn to reflect upon and draw upon strategies used by good language learners in their second language study. Regular homework, quizzes, tests, presentations, and class participation are mandatory (three in-class hours per week plus six hours of required homework). The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Upon completion of this course, students can take 82-172.

Prerequisite: 82-173

82-176 Intensive Japanese Language & Culture: Elementary Level

Intermittent

No course description provided.

82-180 Bilingual & Bicultural Experiences in the US

Intermittent: 9 units

This course focuses on various aspects of bilingualism and biculturalism in the United States, with particular emphasis on the experiences of those who identify as a speaker of a heritage language and/or member of a heritage culture. Some possible topics to be covered include: the nature of bilingualism and biculturalism; the historical and social contexts of bilingualism in the United States; characteristics of languages in contact and bilinguals' language practices; policies around heritage language maintenance in education; and the connection between language, culture, and identity. This discussion-based course is taught in English and is open to all students, whether they identify as bilingual/bicultural Americans, or are simply interested in the course topic.

82-181 Classical Latin: Rome's Cultural and Linguistic Legacy

Intermittent

Why are so many scientific, medical, and legal terms Latin in origin? How can studying a dead language help us learn about living ones? How can studying this ancient language help us understand our modern world? In this course, we will explore these questions through learning the fundamentals of the language itself. We will work towards reading original Classical Latin prose, and consider how aspects of Latin have influenced English and modern Romance languages. In addition, by reading excerpts from a variety of Roman authors, we will contrast Roman ideas about war and conquest, love and grief, science and medicine, drama, and leadership with our own modern conceptions of these topics. We will also discuss the opportunities and limitations of translation. By the end of the course, you will be able to read unadapted passages of Caesar's *de Bello Gallico* (On the Gallic War), and will be able to trace Roman cultural themes down to the modern day. This is a 9-unit course with an optional 3-unit add-on, for students who want to explore an aspect of the reception of Latin language or culture more deeply.

82-182 Local Advocacy for Global Change

Intermittent: 6 units

When countries committed to achieving the Sustainable Development Goals by 2030, they specifically recognized the critical role of local authorities. But how can these local actors engage in global policy discussions, taking into account different cultures and contexts? In this course, students will select a set of local issues, determine how they relate to the Sustainable Development Goals, and identify the relevant international frameworks for taking action. At the end of the course, each student will have developed a brief advocacy plan for linking their local priorities to international objectives.

82-191 Elementary Russian I

Fall: 12 units

This course is for students who have never studied Russian. It begins the Russian language sequence and is offered in the fall semester only. The course takes a communicative approach to teaching basic skills in listening, speaking, reading and writing. Language is presented in communicative contexts illustrating cultural aspects of daily Russian life. The elementary level is also designed to help students learn to reflect and draw upon strategies used by good language learners in their second language study. Daily homework and participation in class are mandatory (four in-class hours per week), as is weekly consultation and conversation practice with a course assistant. A student with prior experience in Russian must take the placement exam. **If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you**

82-192 Elementary Russian II

Spring: 12 units

Elementary Russian II is the second semester of a yearlong beginning Russian sequence. Students who complete this yearlong sequence will acquire the basics of Russian grammar and develop an active vocabulary of approximately 1,000 words. They will learn how to tell simple stories on familiar topics, ask questions, and express their opinions. They will be able to grasp the main ideas of short newspaper articles and understand the gist of straightforward Russian speech. Throughout the course, students will encounter oral, visual, and written content and engage in the interpretive, interpersonal, and presentational modes of communication. A student with prior experience in Russian must take the placement exam.

Prerequisite: 82-191

82-194 Intensive Russian (I & II)

Intermittent: 15 units

This intensive course allows students to complete a yearlong elementary Russian program in one semester and proceed to Intermediate Russian. Students who complete this course will acquire the basics of Russian grammar and develop an active vocabulary of approximately 1,000 words. They will learn how to tell simple stories on familiar topics, ask questions, and express their opinions. They will be able to grasp the main ideas of short newspaper articles and understand the gist of straightforward Russian speech. Throughout the course, students will encounter oral, visual, and written content and engage in the interpretive, interpersonal, and presentational modes of communication. A student with prior experience in Russian must take the placement exam. **If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you**

82-198 Research Training: Modern Languages

Fall and Spring

These courses are designed to give eligible and interested students some hands-on research experience working on a faculty project or in a lab in ways that might stimulate and nurture the students' interest in doing more research. They are open to students who are Dietrich College, SHS, or BHA majors, double majors, and minors who will be second semester freshmen or sophomores during the semester they take the course. F20 TOPICS Section A: Section C: This project involves examination of 17th and 18th century treatises in Spanish that document the uses and consumption of chocolate in Spain and the Americas. Students will assist in researching the evolution and reception of these works and their translations and adaptations.

82-200 Careers, Cultures, & Languages

Intermittent: 9 units

"But what are you going to do with it?" is a question you may have heard from family members and friends when you declared your intention to major or minor in Modern Languages. Many people assume there are no good jobs within the language industry outside of teaching, yet nothing could be further from the truth. The language services industry is a growing sector constantly in need of qualified employees. More than 3,000 different companies in the United States alone employ more than 55,000 people in the language services industry - and the numbers are increasing. In particular, students with double majors can find many lucrative job opportunities. This seminar will take a two-pronged approach to finding a rewarding job with languages: 1) By using design thinking, we will explore what exactly it is that will make you happy in your life. What criteria will your job have to fulfill in order to fit into the lifestyle that is best for you. 2) By taking that knowledge as the basis of our quest for the perfect job, we will embark on a networking adventure, both locally and nationally, where we will research, interview and connect with people from the language services industry and learn about their educational background, experiences, and advice on succeeding in their particular field. By the end of the course, you will have grown your professional network, gathered tools and knowledge for applying for jobs, and developed industry connections to help discover how to make your passion for languages a career. The class will be conducted in English.

82-201 Intermediate French I

Fall and Spring: 9 units

At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of French and francophone cultures will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in French must take the placement exam. Prerequisites: 82-104 or 82-102

82-202 Intermediate French II

Fall and Spring: 9 units

This course is a one-semester intermediate language course intended to give students exciting and fast-paced instruction in French language and culture. Introducing vocabulary sets, core grammatical concepts through cultural texts and strategic interaction, this class will focus on developing academic literacy as well as socio-pragmatic competence (that is to say, what to say to whom, and how) in an interculturally responsive way. To this end, we will incorporate a broad range of learning activities that emphasize a student's active participation. Emphasis will be placed on developing stronger listening and oral communication skills as well as reinforcing reading ability and acquiring greater facility in written proficiency. Consequently, this syllabus is constructed to permit a fair amount of self-instruction through the accompanying grammar reference book and self-guided exploration. F22: The course is an exploration of French language and culture through a nesting of two experiences: (1) playing and analyzing games together as a class and (2) designing games with the objectives of them being used (or usable) by French students/teachers in the classroom (complete with rules and pedagogical guides). This semester, we are trying a new thing, which is to have both advanced students (such as yourself) and intermediate-level students in the same class to try and form a true Community of Practice in which the students will be socialized into a (mostly) French-speaking community of gamers and game designers. This is why the meeting times are 6 hours, more hands-on work, with less independent homework. Prerequisites: 82-201 or 82-203

82-208 Eastern Europe: Society and Culture

Intermittent: 9 units

This course surveys the societies and culture of modern Eastern Europe, from the Baltic States and Poland to the Balkans and Bulgaria. It will attend to this region's complex and turbulent history and consider the dynamics that shape it from geographical, geopolitical, cultural, and socioeconomic points of view. By reading texts by Milan Kundera, Mihail Sebastian, and Olga Tokarczuk, among others, we will explore topics such as the formation of nation states and nationalism, the violent conflicts of the 20th century, the Holocaust, communist regimes, and post-communist political formations. Students will come away with a better understanding of the socio-cultural circumstances that shape present day Eastern Europe. All readings will be in English, and no prior knowledge of Slavic languages or cultures is required.

82-211 Intermediate Arabic I

Fall: 12 units

This course builds on Elementary Arabic II to continue building students' communicative competence at the Intermediate Low-Mid level in Modern Standard Arabic in all four language skills (listening, reading, speaking, and writing) following a proficiency-oriented teaching approach. The course also continues to 1) integrate a spoken dialect to enrich students' background in oral communication; and 2) educate students about various aspects of Arab culture through written and audio-visual materials. Prerequisite: 82-112

82-212 Intermediate Arabic II

Spring: 12 units

This course follows Intermediate Arabic I. It continues to build students' communicative competence at the Intermediate Mid-High level in Modern Standard Arabic in all four skills (listening, reading, speaking, and writing) following a proficiency-oriented teaching approach. The course also continues to 1) integrate a spoken dialect to enrich students' background in oral communication; 2) educate students about various aspects of Arab culture through written and audio-visual materials; and 3) engage in conversation with native speakers through the Natakallam program, virtual sessions, and guest speakers from City of Asylum and other institutions, in order to build their cultural literacy. Prerequisite: 82-211

82-214 Topics in Modern Arabic Language, Literature, & Culture

Fall and Spring: 6 units

An integrated approach to the study of the Arabic language, literature and culture by means of literary and cultural readings. This course explores definitions of culture and analyzes the dynamic role of language in culture and culture in language, with an aim to foster cross-cultural awareness and self-realization while developing proficiency in Arabic. This course is designed to strengthen listening, speaking, reading and writing, within the context of an evolving Arabic culture. F22 A2: The beauty of Arabic is within its flexibility: the way the sentence is built and the freedom it gives writers to create new expressions. Are you ready to take your Arabic language and culture to the next level? Your journey has just begun. Creative Writing and Media is an interactive course that allows Arabic language students to better understand the formal language, idioms, and metaphors, as well as enhance their writing and reading capacity, not just in simple essays but also in literature, short stories, poems, novels, and journalistic reports. This course will provide students with techniques to help them develop their artistic imagination to write long or short texts or poems in Arabic. In addition, the course will allow students to expand their knowledge of the Arab world, its culture, and its literature. Guest speakers will include novelists, editors, and journalists from the Arab world to talk about their writing processes and the general writing and media culture in the Arab world. Prerequisite: 82-112

82-215 Arab Culture Through Dialogues, Film, and Literature

Fall and Spring: 9 units

F23: Minorities in the Middle East and North Africa In today's society that explores Diversity, Equity, and Inclusion (DEI), one ought to ponder if Arab societies have made progress to achieve DEI among groups of other religions (Muslims, Christians, Jews), sects (Sunni and Shi'a), ethnicities (Copts, Nubians, Kurds), Palestinians, LGBTQ, and women. Some of the questions that this course addresses are whether a minority in Arab societies is defined by number or status; the role of education, social norms, and media in approaching issues of skin colors and minorities' rights; the autocratic governments' use of identity politics to serve their own interests; and the historical changes that have shaped citizenship and belonging. This course aims to enrich students' understanding of the diversity of Arab countries and the impact of colonialism, Pan-Arabism, socio-economy, and cultural norms on minorities' status through readings, films/documentaries, music, and data collected via surveys and virtual sessions with students in Arab countries.

82-216 Literature of the Arabic-speaking World

Fall and Spring: 9 units

This course is offered only at Carnegie Mellon's campus in Qatar. This repeatable introductory course explores the Arab world through a thematic or conceptual focus. In spring 2016, the theme will be "Cultural Issues in the West and the Arab World". Coursework will include reading short stories and novels to understand the cultural context that gave rise to specific literary works. Students will also continue to develop their abilities to express their ideas both in speaking and in writing, as well as their listening skills in Modern Standard Arabic.

82-217 Multilingualism and Multiculturalism in the Arab World

Fall and Spring: 9 units

This course brings linguistic and cultural diversity in the Arab world to the forefront through exposing students to the key social issues in the study of multilingualism. To this end, the course will explore and analyze some of the deeply held language ideologies in Arab and international contexts. Topics to be covered in the course include (but are not limited to) multilingualism within and across languages (e.g., multidialectal practices, code-switching between languages, language variation and change), societal and individual multilingualism (e.g. language and identity), multilingualism in institutional sites (e.g. schools, the work place), language policy and planning, and language rights. The course is taught in a seminar, discussion-based format and students will construct projects to explore course topics in a hands-on manner. The course is taught in English and students who wish to take the course as a Modern Languages major or minor elective will need to complete their final project on a topic relevant to the language they study.

82-221 Intermediate German I

Fall and Spring: 9 units

The goal of Intermediate German I is to further develop students linguistic and cultural knowledge, allowing them to feel more comfortable as a user of German. By the end of the semester, students should be able to: use and understand German in everyday situations; communicate effectively in general areas and in individual areas of interest; understand general cultural perspectives in contemporary Germany; and read and understand authentic materials from German-speaking countries. Activities will help develop the four skills and of cultural knowledge. This course focuses on intercultural concepts and will help students see what things Germans view differently from other nations and what things might be similar. Topics will include issues such as travel, politics, immigration, and music. A student with prior experience in German must take the placement exam.

Prerequisites: 82-122 or 82-123

82-222 Intermediate German II

Fall and Spring: 9 units

This course aims to increase your proficiency in all four language skills: reading, writing, speaking, and listening comprehension. You will get practice in speaking and listening through classroom discussions of the readings as well as group discussions of general topics. In addition to this, we will have a thorough grammar review. Overall, there will be a pronounced emphasis on increasing your awareness of different worldviews. We will contrast and compare different German-speaking countries with one another and the diverse cultures that they harbor, as well as your own countries with their cultural and historical idiosyncrasies. Last but not least, we will explore and analyze the cultural context within which various institutions exist and within which cultural norms are constructed.

Prerequisite: 82-221

82-225 Multiculturalism, Ethnic Diversity, and Debates about Them in Contemporary Europ

Intermittent: 9 units

This course will explore ethnic and cultural diversity in contemporary Europe, especially Germany. All of these countries have become increasingly diverse ethnically and culturally over the last few decades, and there have been significant debates about immigration and willingness (or lack thereof) to accept refugees from other parts of the world. Some have celebrated Europe's increasing multiculturalism and diversity, whereas others have criticized it. The goal of the course is to look at both multiculturalism and diversity and also the critics of multiculturalism and diversity.

82-227 Germany & the European Union

Spring: 9 units

This course offers an overview of contemporary Germany, its problems and its promise, with a particular focus on German politics, the German economy, and Germany's role in the European Union and in the world system. Primary topics include: 1) Germany on the World Stage; 2) Germany and the Past; 3) the German political system; 4) the German economic system; 5) the European Union, its challenges, and Germany's role in it; 6) Germany, the EU, and multiculturalism and ethnic and cultural pluralism, including the role played in Germany and Europe by ethnic, religious, and cultural minorities. Each of these topics will take about 2-3 weeks of the course. Students in the course will be required 1) to complete all required course readings (the equivalent of about three books in English, although in most cases we will be reading chapters from books rather than entire books, plus about five separate articles in English), 2) to take five short fifteen-minute quizzes on some of the various themes of the course, 3) to do a book review of a book of their choosing dealing with contemporary Germany and/or the European Union and to make a presentation about that book in class, 4) to write three short (four page) papers on the themes of the course, and 5) to participate in two debates about A) Germany's response to the past; and B) Whether or not Germany and the EU should be more open to ethnic, cultural, and religious minorities.

82-230 Cultural Topics in Chinese Studies

Intermittent: 9 units

FALL 2023: The Pursuit of Happiness in Early Chinese Thoughts and Their Modern-day Applications (section taught in English): Do you claim to be a happy person? If so, why? If not, why not? How do we define "good life" and where can we get it? This course will inspect various responses to these questions in early Chinese thoughts and their modern-day applications from a global perspective. Chinese thoughts and philosophy are the intellectual foundations of Chinese culture throughout history. They represent the love and pursuit of wisdom in Chinese tradition. The course will explore some major schools of thought in early China such as Daoism/Taoism, Confucianism, Buddhism, Legalism, and Mohism, and look at the manifestations of their wisdom in various aspects of contemporary Chinese society, including food, medicine, Fengshui, architecture, painting, calligraphy, and Taichi.

82-231 Intermediate Chinese I

Fall and Spring: 12 units

This course is the continuation of Elementary Chinese II (82-132). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing with the goal of becoming more proficient in daily communication needs. In addition to an ongoing review of basic grammar, a greater variety of expressions and complicated sentence structures will be taught so that students can carry on more sophisticated daily conversations on various topics related to every day life. While equal emphasis will still be on both Pinyin and characters, students will be encouraged to use more and more Chinese characters with the help of Pinyin for communication. In-class and extracurricular activities related to the broad spectrum of Chinese culture will be organized to facilitate language learning using knowledge of the cultural background of the language. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Chinese must take the placement exam.

Prerequisites: 82-135 or 82-132 or 82-134

82-232 Intermediate Chinese II

Fall and Spring: 12 units

This course is the second semester of Intermediate Chinese. More sophisticated grammar points and vocabulary are introduced to help students' listening, speaking, reading and writing skills reach the intermediate level. The course also helps students prepare for advanced Chinese by exposing them to formal and written expressions and increasing their "media literacy". This is accomplished by systematically and gradually selecting and blending idiomatic expressions, and authentic printed materials into the texts and exercises. Activities related to the broad spectrum of Chinese culture are organized to facilitate language learning with knowledge and analysis of the cultural background of the language.

Prerequisite: 82-231

82-234 Topics in Chinese History

Intermittent: 9 units

In fewer than three decades, the People's Republic of China has transformed itself from an underdeveloped and reclusive state to become the world's next probable superpower. Divided roughly into three sections, this course examines: 1) the miraculous economic development that made China's rise possible; 2) the political system that allowed the Chinese Communist Party to rule over that rise; 3) China's rising global stature and its implications for the rest of the world. In combination these sections allow us to understand how China's rise happened and what it means for the future of the entire globe. Issues addressed include: economic development, inequality, cybersecurity and internet censorship, Intellectual Property Protection, China's influence in Africa, China's military capability, and the Beijing Consensus. The goal of this course is to prepare students for a world where China is increasingly important, but also to ask how China got to where it is today, and where it is going as chances are highly likely that students in most any area of study will be influenced by China's future. This course and all source materials will be in English. No knowledge of Chinese is required.

82-235 Fables, Legends and Stories from Ancient Chinese Civilization

Spring: 9 units

By reading, analyzing, and presenting on traditional fables, short stories, and articles on the lifestyle and social changes in China, this course encourages students to look into the historical development of ancient Chinese civilization and the complex relationship between traditional China and its modern counterpart. Activities related to a broad spectrum of Chinese literature, culture and society are organized to facilitate language learning, cultural analysis and cross-cultural comparison. Topics of this course include, but are not limited to, the Chinese creation myth, famous historical events and figures, Chinese herb medicine, and Chinese wedding customs. In addition to expanding students' knowledge of Chinese society and culture and the socio-cultural influences on Chinese language, this course will also help students extend their Chinese vocabulary and improve Chinese reading and writing skills and proficiency. With the help of classroom discussion and debate, reading and writing assignments, and cultural presentations and projects, students are expected to develop long-term retention of Chinese language and in-depth understanding of Chinese culture and society from a global perspective.

Prerequisites: 82-135 or 82-231

82-236 Intensive Chinese Language & Culture: Intermediate Level

Spring

No course description provided.

82-238 Topics in Chinese Culture

Intermittent: 9 units

Courses offered under this repeatable title will focus on aspects of modern and contemporary Chinese culture, including, for example, literature, the arts, theater and music, and gender studies. Through the critical analysis of original sources in translation, film, as well as outstanding works of scholarship, students will gain a deeper understanding of important developments in modern and contemporary China and will learn how to locate and evaluate sources of knowledge about China for future study. This course and all source materials will be in English. No knowledge of Chinese is required. Past titles have included Gender and Sexuality in China: Tradition and Transformation. F22: This course covers the most important topics and texts in both environmental humanities and modern Chinese literature, film, and culture. Thematically, this course focuses on deforestation, chemical pollution, climate change, ethnicity, toxic waste, and the extinction of species. The readings include literature, film, popular culture, environmental history, and new media. We will also read important theories as analytical tools by Rob Nixon, Karen Thornber, Ursula Heise, Dipesh Chakrabarty, Anna Tsing, William Cronon, etc. Each thematic topic is paired with a key concept in environmental humanities so that students can situate their study within the scholarship of environmental humanities. We will also explore Chinese environmental imaginaries and realities from East Asian, comparative, global, as well as interdisciplinary perspectives. All materials have English translations; No Chinese language required. Class discussions in English.

82-239 Crazy Linguistically Rich Asian Languages

Intermittent: 9 units

The languages spoken in China and Japan differ from those spoken in the west in a number of striking ways. In this 9-unit course, students will gain an understanding of the sound systems, morphosyntax, lexicon, writing systems, dialects, and varieties of Chinese and Japanese. Students will also learn how these neighboring languages and cultures have interacted and changed over time. The knowledge acquired in this course will be equally beneficial to those learning one of these languages and to those simply interested in better understanding East Asian languages and cultures.

82-240 Pathways in Spanish: Exploring Personal and Professional Opportunities

Intermittent: 3 units

Spanish, the second most widely spoken native language in the world, has nearly 500 million native speakers, and is an increasingly important language throughout the US and abroad. This course will serve as an opportunity for students to consider ways that the study of the Spanish language and of Spanish-speaking cultures can serve to open doors and enrich us both personally and professionally. We will consider how your work in Hispanic Studies connects with other majors and minors, as well as looking at a variety of opportunities in terms of internships, scholarships, and future career paths. The course will include visits from some local organizations and businesses where Spanish is regularly used, and serve to connect students with alumni from a variety of different fields whose jobs have utilized Spanish and/or knowledge of Hispanic cultures. This course is open to students of all years and levels of Spanish.

82-241 Intermediate Spanish I

Fall and Spring: 9 units

Intermediate Spanish I is the first part of a two-semester course sequence (82-241, 82-242) designed to familiarize students with the cultures and perspectives of the Spanish-speaking world. Students will develop self-expression across a range of culturally significant topics, improving their speaking, listening, reading, and writing skills while working with longer passages of language in context through reading, writing and listening/viewing (e.g. tv series, movies, short novels, plays) and frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. The course provides extracurricular opportunities to interact with members of the Spanish-speaking community.

Prerequisites: 82-144 or 82-142

82-242 Intermediate Spanish II

Fall and Spring: 9 units

Intermediate Spanish II is the second part of a two-semester course sequence (82-241, 82-242) designed to familiarize students with the cultures and perspectives of the Spanish-speaking world. Students will develop self-expression across a range of culturally significant topics, improving their speaking, listening, reading, and writing skills while working with longer passages of language in context through reading, writing and listening/viewing (e.g. tv series, movies, short novels, plays) and frequently working in groups and pairs, and utilizing technologies that enhance learning opportunities and promote skill development. The course provides extracurricular opportunities to interact with members of the Spanish-speaking community.

Prerequisites: 82-241 or 82-243

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view/)

82-245 New Directions in Hispanic Studies

Intermittent: 9 units

SPRING 2021: COVID Cultures - Narratives from a Pandemic This course is designed to investigate the narratives of the COVID pandemic within a global context focusing on the humanistic and cultural. The geographic focus will be the Spanish-speaking world. Readings will begin with the philosophers Seneca and Maimonides and continue through history such that the analyses stem from the students' development of their own concept of narratives of the body and pandemic. We will concentrate on the stories and experiences of those disproportionately affected by the pandemic in order to attempt to amplify those voices. In addition, we will question standards of practice of health and medicine in the US and the effectiveness of those standards when applied to various Spanish-speaking cultures both within and outside of the US. Conversely, we will attempt to understand what the US can learn from other cultures. This course will be taught in English.

82-247 US Latinos Literature

Intermittent: 9 units

FALL 2023: Mapping Dreams and Nightmares: Seeing and Writing the US-Mexico Border This course will focus on the US-Mexico border, with particular emphasis on visual representations of the border from both the US and Mexico, and on the unique, vibrant *fronteriza* cultures that result in the space between and between. The course will emphasize key moments and events in the history of the border, including for example the Mexican Revolution, the creation of the border patrol in the 1920s, the Bracero program, Operation Wetback, the Chicano movement, Operation Gatekeeper, and will consider how visual and textual representations have responded to and been conditioned by the political and economic relationship between the US and Mexico, particularly in the wake of neoliberal policies. We will draw on a wide variety of materials, including film, video, visual arts, performance, border theory, and literary and journalistic texts. (This sections is taught in English)

82-248 Topics in Social Change

Fall and Spring: 9 units

FALL 2019: Arts, Media and Social Change: The Arts in Revolution Cuba and Nicaragua. This course will examine the Cuban and Nicaraguan Revolutions and their relationships to artistic production in a larger socio-political context, considering the complex dynamic of both fomenting creative expression, while also (on occasion) stifling its content. 2019 marks 60 years since the Cuban Revolution, touted as the victory of a tiny island over US imperialism, and 40 years since the triumph of the Sandinistas in Nicaragua - both cases garnering broad international attention due to their importance in Cold War political agendas and the subsequent interplay of US-Soviet relationships in the US' "backyard". While quite different, the Cuban and Nicaraguan Revolutions shared an inherent understanding of the value of capturing the public imaginary and support through the use of the arts to promote their messages and as such, invested significant resources in the promotion of creative production. This course will interrogate the relationships between political and artistic movements, examining for example the formation of ICAIC (Instituto Cubano del Arte e Industria Cinematogr and #225;ficos) in Cuba and the mural movement in Nicaragua. Once these political movements had triumphed, how did artists negotiate the institutionalization of revolution? How did the role of prominent cultural workers like Tomas Gutierrez Alea (Cuba) and Ernesto Cardenal (Nicaragua) evolve as these revolutions aged? We will also question the dynamic between artists whose works express discontent and the State - what was/is the space for dissent? How do artists of newer generations create space for different types of expression that diverge from what early revolutionary moments considered to be transformative? Decades later with deeply entrenched governments, what now is the relationship between the arts and socio-political change?

82-249 Hispanic Language & Cultures for the Professions

Fall and Spring: 9 units

This course focuses on building proficiency in Spanish-language communicative skills and cultural awareness for business contexts in the very diverse Spanish-speaking world, one with over 437 million speakers worldwide. Students will be introduced to a variety of contexts in the Spanish-speaking world of global business and finance through multimodal materials, e.g., newspapers, film, advertisements, and other relevant texts. By examining different scenarios such as job interviews, international trade, and workplace environments, students will build knowledge of vocabulary and develop a real-world understanding of appropriate linguistic, cultural, and discipline-specific practices.

Prerequisite: 82-241

82-250 Digital Realities: Introducing Immersive Technologies for Arts and Culture

Intermittent: 9 units

As Immersive and spatial media increasingly feature in our cultural life, innovators are needed who can blend technological skills with creative imagination and critical humanistic practice. This introductory course aims to enable hybrid technologists, media-makers, and storytellers who can create mediated experiences that advance diversity, equity, and inclusion in the creation of augmented, immersive, and spatial media. You will construct, but also deconstruct immersive and augmented experiences with respect to the cultural, socio-emotional, and embodied aspects of human experience through a process of play, exploration, and experimentation. You will author original narratives and prototype spatially mediated experiences while attending to the aesthetic considerations, humanistic concerns, and design conventions defining this emerging mode of cultural production.

82-253 Korean Culture Through Film

Intermittent: 9 units

South Korean cinema became one of the most vibrant local film industries at the end of the last century, attracting great attention from both the public and scholars, not only at home but abroad as well. Intriguingly, its renaissance involves a strong tendency to revisit and reassess a variety of historical traumas from the last century, which makes it an important venue for discussing the evolution of modern Korean society and culture. This course thus explores works of acclaimed filmmakers such as Im Kwon-taek, Park Kwang-su, Jang Sun-woo, Hong Sang-soo, Lee Chang-dong, Park Chan-wook, Bong Joon-ho, Kim Ji-woon, etc. to enrich our understanding of social and cultural formations in South Korea over the last century. In examining the voices from the Korean peninsula whose history had remained obscured until recently, this course also aspires to contribute fresh perspectives to broader geopolitical settings such as East Asian and Pacific Rim discourses.

Prerequisite: None

82-254 World of Korea, Then and Now

Intermittent: 9 units

Over the past two decades or so, South Korea has grown to become a major player, not only in East Asia, but also in world politics, economy, and culture. While Korean society thus certainly deserves enough attention as a venue for discussing the changes occurring across the world, its history and culture still remains less known than it should be to the outside world including the U.S. This course thus aims to offer an opportunity to explore the evolution of Korean society and culture over the course of its modern history. By enriching the knowledge of Korean history, it also hopes to help the student gain fresh perspectives on broader contexts such as East Asia and the Pacific Rim. This course covers a broad range of time periods: the colonial era to the present. Yet designed to inspire critical approach rather than just offer sketchy overviews, it is structured around key sociocultural issues such as colonial legacies, the cold war paranoia, dictatorship, democratization, national culture, gender politics, diaspora, globalization, hallyu (k-pop/k-drama), etc. To better serve its objectives, this course also utilizes diverse forms of texts: historical studies, critical essays, literary works, films, TV dramas, and music videos. Prerequisite: None

82-261 Intermediate Italian I

Fall: 9 units

This course begins a two-semester course sequence (82-261, 82-262) for intermediate-level students. At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of Italian culture will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in Italian must take the placement exam.

Prerequisites: 82-163 or 82-162

82-262 Intermediate Italian II

Spring: 9 units

At the intermediate level, students will continue to improve listening, speaking, reading and writing skills with the goal of becoming more proficient in daily and extended communication needs. In addition to an ongoing review of basic grammar, a greater variety of grammar, expressions and complicated sentence structures will be taught so that students can carry on more sophisticated conversations on various topics. In-class activities and homework using authentic texts related to the broad spectrum of Italian culture will be used to integrate language learning with content and culture. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory. A student with prior experience in Italian must take the placement exam.

Prerequisite: 82-261

82-263 Intensive Italian Language & Culture: Intermediate Level

Intermittent: 9 units

No course description provided.

82-267 Beyond the Mafia and Michelangelo

Intermittent: 9 units

Beyond the Mafia and Michelangelo: Italy Unmasked Eclipsed by the consumer obsessions of tourists and the most well-known figures of Italian history, the uniqueness of Italy, offering distinct cultures in the north, central, and south, is rarely understood by outsiders. In this course, students will discover an Italy rich with cultural variants, radically diverse histories, customs, cults, and superstitions, in addition to physical expressions of culture in cooking and clothing, art and architecture. Students will identify and critically analyze diversity within the peninsula and its islands, and expand their awareness and understanding of the role of culture in behavior. Film, documentaries, and readings from epistolary and literary sources will help reveal a more profound Italy, for example, the science of Dulbecco (the Human Genome), the architecture of Trulli conical houses, the religious importance of Pitigliano ('Little Jerusalem'), and the immigration problems of San Marino. Coursework will include class participation, readings, film viewings, and writing. Final projects will be based on interviews and oral histories with the Italo-American community in Bloomfield (Pittsburgh), leading to critical comparisons of that population with Italians in Italy. This course is offered in English.

82-268 Italian Film: Hidden Agendas from Cincitta

Spring: 9 units

Mussolini declared: "Cinematography is the most powerful weapon." Accordingly, the films in this course explore the political and societal cultures of Italy, and their subsequent interrelationships and effects on Italian film. Students will follow a cinematic journey that begins with silent cinema, leads to the historical narrative of WWII and the resistance fighters of neorealism, then to the political analysis of the migrant crisis of la questione meridionale (the problem with the south) and finally takes on a more comical vein with la commedia all'italiana (Italian comedy) finishing with a unique solution to the problem of unemployed graduates. Outcomes include analyses of the formal aspects of Italian cinema, the crumbling of post WWII political parties, the emergence of new political figures, and the "precarious" generation of college graduates forced to work for meager wages and no rights while their peers leave the country to find work causing the so-called brain drain of Italy. Films can be viewed in the Modern Language Resource Center or streamed online through CMU's Kanopy

82-269 Immersive Digital Storytelling: Using VR/AR to Explore, Language Culture Identity

Intermittent: 3 units

In this course you will enjoy a series of remote and then in-person workshops, setting the groundwork for their own practical projects. Often perceived as a technology of tomorrow, students will be introduced to storytellers and content creators currently working with Virtual and Augmented Reality and other Immersive media to tell stories about people, communities, cultures, and histories in compelling and engaging ways. Using readily available smartphone apps and consumer-ready cameras and head-mounted displays, students will be able to create their own short immersive films and gain a better understanding of this important and emerging field. You will produce your own short digital story using the technologies that we explore through this class. Your story will explore themes of identity, language, and culture, asking you to relate experiences and reflect on ways that you connect and interact with cultures around you. We will ask questions about the affordances of immersive technologies, how we can use them to tell stories of culture and how creators and artists are different themes through their work.

82-270 Technology in Japanese Culture and Society

Intermittent: 9 units

This course explores various ways technology interacts with Japanese culture and society. On the one hand, technology has greatly changed Japanese culture and society, but on the other hand, the actual use of technology in Japan has been significantly influenced by Japanese culture and society. As an illustrative example, the course takes up robotic technology and examines how it has been imagined in culture (e.g., anime, manga) and implemented to resolve social issues (e.g., shrinking labor force) by Japanese people. It seeks to show how cultural and social contexts dictate the way technology has been put to use to satisfy the material and other desires of people. This course is taught in English and has no prerequisites. No previous knowledge of Japanese language is required. This course can be taken as an elective course for Japanese majors and minors. The course starts with a vision of society as demonstrated in anime featuring robots (e.g., Astro Boy and Gigantor in the 1960s) and in the Japanese government's robot initiative, Innovation 25, for robotizing Japanese society by 2025. In this vision, people and robots will share a deep emotional bond and live together harmoniously. Then, the course discusses various topics in the vision including a family with a robot, genders of robots, laws of robotics by Asimov and Tezuka governing human-robot interactions, robot rights and human rights, "cyborg-ableism" (disabilities should be overcome by using robotic technology), and a funeral or memorial rite for inoperative robots and a "New Age" Buddhism. Finally, it speculates on the extent to which the Japanese human-robot cohabitation scenario has been realized and the extent to which the scenario remains a product of imagineering (melding science and fantasy to create believable make-believe worlds).

82-271 Intermediate Japanese I

Fall and Spring: 12 units

This course is the first part of a two-semester course sequence (82-271, 82-272). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing skills with the goal of becoming more proficient in daily communication needs, and takes an integrated approach to the study of Japanese language and culture, consisting of grammar review, reading, and intensive practice in written and spoken Japanese. Course materials include authentic audiovisual and written texts in addition to the assigned textbooks. Also integrated are cultural explorations through direct interactions with native speakers. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Japanese must take the placement exam. Prerequisite: 82-172

82-272 Intermediate Japanese II

Spring: 12 units

This course is a sequel to Intermediate Japanese I (82-171). At the intermediate level, students will continue to improve the basic skills of listening, speaking, reading and writing skills with the goal of becoming more proficient in daily communication needs, and takes an integrated approach to the study of Japanese language and culture, consisting of grammar review, reading, and intensive practice in written and spoken Japanese. Course materials include authentic audiovisual and written texts in addition to the assigned textbooks. Also integrated are cultural explorations through direct interactions with native speakers. Regular homework, quizzes, tests, presentations, essays, and class participation are mandatory (four in-class hours per week). A student with prior experience in Japanese must take the placement exam. Prerequisite: 82-271

82-273 Introduction to Japanese Language and Culture

Fall and Spring: 9 units

This course is an introduction to modern Japanese culture, examining Japanese society, its socialization processes, and the role of language in expressing, transmitting and maintaining social structure and cultural values. Learning key concepts to better understand Japanese culture and society from the post war to present-day Japan, students develop a range of skills to analyze cultural perspectives from observable behaviors and social phenomena. Students explore cultural diversity in relation to the traditional view of Japan's homogeneity. This course is taught in English and is intended for those who want to gain better understanding of modern Japanese society and of their own cultural identities, as well as for students of the Japanese language.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view)

82-275 Queer Representations in Contemporary Literature and Culture from Japan

Intermittent

This course will survey queerness in contemporary Japan from the 1980s to the present. Though literature will be the primary focus of this course, we will also look at material from a variety of media including cinema, poetry, manga, and television. The goal is to look at how queerness has been depicted in recent years by a variety of authors and creators, whether or not they happen to be queer themselves. The course will be divided into four large units consisting of approximately four weeks each: Unit One - A Brief Historical Survey; Unit Two - Japanese Literature as Pre-AIDS/Post-AIDS; Unit Three - Queerness on the Border and On the Borders of Queerness; Unit Four - Queerness in Film, Poetry, and Manga.

82-276 Intensive Japanese Language & Culture: Intermediate Level

Intermittent

No course description provided.

82-278 Japanese Film and Literature: The Art of Storytelling

Intermittent: 9 units

The course covers modern Japanese literature (from 1868 to the present) and post-war Japanese film (from 1945 to the present). The modern film and literature have inherited unique premodern characteristics such as an open-ended plot without any closure, a non-linear as well as linear way of storytelling, and a preference of atmosphere and beauty over a structured plot. On the other hand, partly owing to the Western influences, they have seen innovations in the art of storytelling (e.g., contextualization of modern self in an open-ended story, filming techniques). The course focuses on the artistic media (e.g., language, sound, color, film techniques) of each film and literary work and their interactions with the plot and the historical and social contexts of each work. It also explores how the art of storytelling is in tandem with the vicissitudes of human condition as illustrated in Japan's variety of films and literature in the twentieth and twenty-first century. Analyses of each storytelling not only reveal cultural dynamics behind Japanese modernity, but also invite students to find new insights into Japanese culture and their ways to perceive our globalized world. What kind of cultural exchanges took place between modern Japan and the West? How are Japan's traditional values transformed in the face of modern technicalization and industrialization, compared to the modernization of other countries? And, in turn, what kind of impact has modern Japanese culture had on today's world? Tackling these questions among others, the course also extends to such issues as the legacy of traditional Japanese culture, the modern Emperor system, the World War II experiences, emerging voices of minorities and the popular culture (e.g., anime and subculture).

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view)

82-279 Anime - Visual Interplay between Japan and the World

All Semesters: 9 units

In contemporary Japanese culture, anime plays a vital role, unfolding a wide range of non-linear as well as linear ways of storytelling with its distinct modes of visual representation, such as character designs and vibrant use of colors to reconstruct the environment/social reality, and complementing to other forms of culture (e.g., literature, film, and art). This course explores Japanese anime's appeal to the international viewers today, centering on cultural/social analyses of animated works such as the fantastic of the Studio Ghibli production and Cyberpunk's post-apocalyptic worldview in consultation with the scholarship of anime as a global cultural phenomenon. Equally important are to locate the origin of Japanese animation, which is also to be investigated through analyses of the prewar and postwar works of animation in conjunction with related forms such as manga, or comic strips (e.g., Osamu Tezuka's works that was initially inspired by Disney) and to discuss the potential of anime as an art form.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view)

82-280 Bilingual & Bicultural Experiences in the US

Fall: 9 units

What does it mean to be bilingual in the USA, when approximately 80% of Americans are monolingual English-speakers? In this course, we will learn about the nature and experience of bilingualism and biculturalism (past and present) and how it shapes different perspectives and worldviews and #8212;within an individual, between individuals, and on a larger (societal, cultural) level. The course highlights the experiences of groups such as immigrants, racial/ethnic minorities, indigenous communities, and users of signed languages to foreground experiences that may be similar to or different from those of the students. We use a variety of resources (e.g., social media, film and documentaries, historical documents, literature, music, art) to accomplish this, and students are encouraged to be creative in the ways they design their own hands-on projects. This discussion-based course is taught in English and is open to all students, whether they identify as bilingual/bicultural, or are simply interested in the course topic.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view/)

82-281 Contextual Thinking

Intermittent: 9 units

FALL 2022: Pandemic Pop Cultures Living through a global pandemic is new, challenging, and downright difficult. And yet, pandemics have existed for centuries. What might we gain from viewing our current reality through cultural and historical lenses that focus on stories from around the world that attempt to explain pain, family, medicine, humor, and even division? This course is designed to investigate the narratives of pandemic within a global context focusing on the humanistic and cultural, such that through this analysis we might arrive at a more robust understanding of our current times. We will concentrate on stories as communicated through media sources, literary texts, journals, and art in order to better situate our own ways of thinking.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view/)

82-282 Interpreting Global Texts & Cultures

Intermittent: 9 units

Literature, film, music, art, theater, and other forms of humanistic artistic expressions, play an important role in society. Few moments in life are as moving as listening to the right song at the right time, and many of us can list films and/or books that have shaped who we consider to be. Beyond the individual level, artistic expressions have also influenced revolutions, businesses, science, politics, and the list goes on and on. Yet, we often take culture and artistic expressions for granted. What is their role and value in society? How can we interpret these cultural artifacts? Is there a right or wrong interpretation? These are some of the questions we will explore in this class.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view/)

82-283 Language Diversity & Cultural Identity

Fall and Spring: 9 units

Culture, language, and identity are intimately tied together. Individuals, families, communities, and nations identify themselves in relation to the language or languages they speak. Local, national, and international governmental organizations make choices about the language or languages they recognize and use for political and economic affairs. The United Nations even recognizes language as integral to maintaining the cultural heritage of communities and peoples around the world, and the freedom to choose one's language of expression as a universal human right. In this course, we will explore a variety of questions, advantages, and challenges related to language diversity and cultural identity across the globe. Our main focus will be on contexts of multilingualism that is, contexts in which two or more languages may be used. Adopting a comparative case study approach, we will explore the following themes: (i) The historical underpinnings of language diversity and its consequences for cultural identity today (e.g., migration, colonization, conquest); (ii) How language diversity and cultural identity shapes, and is shaped by, local, regional, national, and international politics; (iii) The relationship between language diversity and language use and visibility in public spaces (i.e., the linguistic landscape); (iv) Relations between linguistic communities (e.g., majority and minority language users) and the sense of belonging to a culture. The course is taught in English. Students who wish to take the course as a Modern Languages major or minor elective will need to complete their final project on a topic relevant to the language they study.

Course Website: https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view (https://drive.google.com/file/d/1RU2iXs7Vyc-6F-HRozPu7_YdV7oYuOGn/view/)

82-284 Multicultural Pittsburgh: VR Storytelling

Fall and Spring: 9 units

Pittsburgh is known for its multicultural landscape and communities. Through this course, students will explore the cultures, identities, languages, and groups that have historically shaped, and are still shaping Pittsburgh. Students will develop digital documentation of the city's communities, for example using video, photography, audio podcast, and focus on immersive VR. Through active learning, students will employ approaches such as interviews, research and exploration of the city through its data and social history. Students will craft their work in the Askwith Kenner Global Languages and amp; Cultures Room housed in the Tepper Building, and at the end of the course, the work will be on exhibit for the campus community and the wider public. This course will develop your research and fieldwork skills, media creation skills and multicultural literacy. This course will meet two days a week for four weeks, followed by self-directed study and instructor support, with video projects due two weeks after. This is a course focusing on the use of 360 Immersive Virtual Reality Video for students to produce, shoot, edit and publish their projects. For an additional 3-units, students will explore and analyze the use of VR Video in language and cultural documentary, writing an appreciation of this form of storytelling using examples from news and VR documentary producers.

82-285 Podcasting: Language and Culture Through Storytelling

Fall: 9 units

Do you love stories? Stories told on the radio have always had significant power. For example, the 1938 War of the Worlds broadcast by Orson Welles was so effective that it panicked the entire United States. Today, podcasts such as Serial, This American Life, and The Moth have the same power to tell stories and provide audiences with rich, intimate and immersive audio experiences while often supporting diversity and giving voice to minorities and those under-represented in mainstream media. Owing its rising popularity to the ease and accessibility of production and distribution, there has never been a better time to create and tell stories in audio. In this course students will take on the role of podcast producers, learning while creating a series of podcasts that explore linguistic and cultural landscapes with the goals of educating and entertaining. Possible audio resources include field interviews with native speakers in their own language, allowing student producers to document informants' personal histories and aspects of their life related to culture, multilingualism, or political, social or environmental issues. Students will blend studio recordings with interviews and/or suitable "found" recordings, music, and sound. Coursework will include skill development on audio recording and podcasting, production management, creative thinking, materials sourcing, and giving and receiving constructive feedback from classmates and varied audiences on team and individual projects. The course will be offered in English.

82-286 Cultural Complexities

Fall and Spring: 9 units

FALL 2022: Section A: This course will explore ethnic and cultural diversity in contemporary Europe, especially Germany. All of these countries have become increasingly diverse ethnically and culturally over the last few decades, and there have been significant debates about immigration and willingness (or lack thereof) to accept refugees from other parts of the world. Some have celebrated Europe's increasing multiculturalism and diversity, whereas others have criticized it. The goal of the course is to look at both multiculturalism and diversity and also the critics of multiculturalism and diversity. Section C: In this course, students will gain an understanding of the linguistics of various East Asian languages. Students will learn how one's own experiences, worldviews, society, and culture can be shaped by language. Understanding these principles is essential in creating more global and intercultural citizens. Section D: Students will examine multicultural situations in Japan, where foreign migrants, indigenous peoples, and hafu live and work with Japanese people, from historical, political, economic, social, and cultural perspectives. They will also be asked to reflect on their own cultural contexts for understanding the cultural diversity of their own society. Section E: In the days when threats were constant, human beings needed to assess possible danger quickly. Today, before even speaking, our brain assesses and categorizes others. Needless to say, these quick judgements are inaccurate and based on what is visible or perceivable: clothing, health, etc, and even on where we encounter each other: in a bar, a library, or a laundromat. We don't realize the influence of our own cultures/identities on our assessments. Through data, students will uncover themes leading to feelings of a lack of inclusivity and create plans to help us develop deeper understanding and acceptance in the CMU community.

82-287 Multicultural Immersion - Relating Your World in Virtual Reality

Fall: 6 units

In this unique course, taught across two campuses in Pittsburgh and CMU-Q, Doha we will explore the ways cultures and identities often intersect, relate and contradict one another. Using Virtual Reality (VR), a technology that provides a type of immersion, we can see the world through other people's points of view. But can we really harness this technology to tell stories about languages and cultures, can we really empathize and understand another culture using VR? To discover the affordances of VR, we will use this immersive technology to tell stories and relate our understanding of the world for others to see, thus exploring cultural understandings. Learning through telecollaboration, in online, virtual and in-person workshops, this will be an opportunity to collaborate, blend ideas, gain valuable skills and build on new experiences. During the course, students will create 360 video outcomes that others will view and experience through headsets and immersive spaces. No technology knowledge is required.

82-288 Everyday Learning: Designing Learning Exp in Times of Unrest & Uncertainty

Fall and Spring

Could you make complex ideas accessible and engaging to learners everywhere? Could you use what you know to make society better, teach as an agent of social change? In these times of Covid-19 many people have used learning to stay connected with friends and communities, leading to a groundswell in teaching and learning online. In this course you will develop learning experiences using a variety of instructional methods in a range of contexts. Underpinning our work with ideas from philosophers and educators, we will explore the democratization of education in a post-Covid world and consider a shifting educational landscape inspired by the Black Lives Matter protests. We will look at the response from museums, libraries, cinemas, and civic spaces to better meet the diverse needs of learners in their communities. For our assessed projects, we will design and produce instructional videos, animation, audio content, paired with worksheets, talks, paper-based instructional materials. This is a 6-unit course (with an additional 3-unit written component for 9 units).

Course Website: <http://kenner.dotsandspaces.uk/blog/courses/>**82-290 Transformative Learning through Cross-Cultural Analysis**

Fall

This course seeks to prepare students for informed, critical, and transformative engagement with communities other than their own, in particular this course will engage students who have or are preparing to study abroad. We will examine some theoretical debates about learning in study abroad contexts and about the development of intercultural capacities as frameworks for the class. Students are encouraged to approach past and present societal and personal concepts, issues, themes, and problems globally and locally using a student-centered, discovery-focused, inquiry-based approach to analyze multiple perspectives. A primary course objective is for students to critically discover how and why societies dictate what people think about things, promote personal values and assumptions, and the resulting impact of social discourse and dominant norms on cross-cultural relations. The goal is that students discover how their own habits, behaviors, and actions can be influenced or transformed by this critical cultural analysis approach. In addition to analyzing their own behaviors, students will also conduct research on specific norms and cultural practices in different global contexts, according to their interests. The instructor's role will be to provide content and structure, encourage students to contribute additional content, and supervise students guided inquiries and case-based projects (written, oral, visual, digital).

82-291 Intermediate Russian I

Fall: 12 units

This course is designed for students who have taken two semesters of Russian at Carnegie Mellon or the equivalent. It is offered in the fall only. This course furthers communicative proficiency through intensive practice in written and spoken Russian. Complex grammatical structures and stylistic variations are mastered and extensive vocabulary is acquired. Through reading materials, fictional and non-fictional, acquaintance is made with the basic components of Russian cultural literacy as well as the distinctive cultural aspects of daily Russian life. Attention is directed toward the dynamic interaction of language and culture in order to foster cross-cultural awareness. Attendance is required at three-hourly class meetings per week, as is weekly consultation and conversation practice with a peer language assistant. **If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you**

Prerequisites: 82-194 or 82-192

82-292 Intermediate Russian II

Spring: 12 units

In this intermediate course, students will review the basics of Russian grammar, develop listening comprehension, and expand their vocabularies and recognize the conversational, artistic, and academic usage of Russian. They will learn to relate simple narratives on familiar topics, express their opinions, ask questions, and speak about hypothetical situations. Students will be able to grasp the main ideas of newspaper articles and hold straightforward conversations with native speakers. In addition to working with the course textbook, workbook, and website, students will conduct a semester-long research project simulating the experience of living in a non-Russian region or country where Russian is frequently spoken. Students will compare and contrast everyday life in the Russian-speaking world with their own worldview, with special attention given to the cultural and ethnic diversity of the global Russophone community. Students will also utilize Russian-language texts and media to explore the historical formation of the Russian Empire and the Soviet Union, as well as the relationships between former Soviet republics and the wider world today. Students will also consider the historical development of the Russian language and the influence of other cultures and languages in producing the modern language we speak today.

Prerequisite: 82-291

82-293 Russian Cinema: From the Bolshevik Revolution to Putin's Russia

Intermittent

"Last night I was in the kingdom of shadows," said the writer Maxim Gorky in 1896 after seeing a film for the first time. "How terrifying to be there!" Early film inspired fear and fascination in its Russian audiences, and before long became a medium of bold aesthetic and philosophical experimentation. This seminar-style course surveys the development of Russian and Soviet film, paying equal attention to the formal evolution of the medium and the circumstances historical, cultural, institutional that shaped it. We will examine Sergei Eisenstein's and Dziga Vertov's experiments with montage in light of the events of the Bolshevik Revolution and the directors' engagement with Marxism; Georgi Alexandrov's and the Vasiliev brothers' Socialist Realist production against the backdrop of Stalinist censorship; Andrei Tarkovsky's and Kira Muratova's Thaw-era films within the broader context of New Wave Cinema; and the works of contemporary directors, including Aleksei Balabanov, Alexander Sokurov, and Andrey Zvyagintsev, in connection with the shifting social and political landscape of post-Soviet Russia. Besides introducing students to the Russian and Soviet cinematic tradition, this course will hone their skills in close visual analysis. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

82-294 19th Century Russian Masterpieces

Intermittent

In the 19th century, Russian writers produced some of the most beloved works of Western literature, among them Dostoevsky's *Crime and Punishment* and Tolstoy's *Anna Karenina*. These novels continue to captivate audiences and inspire adaptations in theater, film, and television. This course will examine the fertile century that yielded such masterpieces. In addition to the works mentioned above, students will encounter texts by writers who may be less well known but are no less significant, including Pushkin, Lermontov, Gogol, Chekhov, and Pavlova. We will consider the social and cultural circumstances in which these works were produced and reflect on the reasons these Russian masterpieces have appealed to audiences well beyond the Russian-speaking world.

82-295 20th Century Russian Masterpieces

All Semesters

At the beginning of the 20th century, the Russian Empire underwent a series of dramatic changes in quick succession: industrial modernization, the unsuccessful 1905 rebellion, terrible losses in the First World War, finally culminating in the 1917 October Revolution. The literature and culture of the era were deeply impacted by these upheavals as artists and writers of the era attempted to capture and convey the world rapidly shifting around them. This course will acquaint students with canonical texts from 20th-century Russian literature and will also examine the highly specific context in which they were produced. From the fin-de-siècle aesthetics of a crumbling Russian Empire to the avant-garde experimentalism of the Russian Revolution and Civil War era, to the establishment of Socialist Realism and the implementation of a Totalitarian regime under Stalin, the course invites students to think about both the realities of life and artistic production in a rapidly transforming country as well as the ways in which these works bring contemporary readers to the inner lives of Soviet citizens.

82-296 World War I - the View from Paris & St. Petersburg

Intermittent: 6 units

The course will examine the history of the First World War from a unique perspective by focusing especially on two of the Allied powers: France and Russia. In addition to an overview of political and military events, we will study the experiences of soldiers and civilians in the trenches and on the home front. The war had profoundly disruptive effects on both countries, and we will learn about the political and social consequences, including the 1917 revolution in Russia, the French Army mutinies, and the longer-term effects on gender roles, the workers' movement, international relations, and artistic expression. The course is open to all students, including those who have previously studied the First World War in some detail. And if you are able to read documents in French, Russian, or both languages we will find an opportunity for you to put those skills to use in this course.

82-297 Russian and Soviet Science Fiction

Intermittent

This course explores the longstanding tradition of science fiction literature, film, and art in the Russian, Soviet, and post-Soviet world. How does the future-oriented world of science fiction look and operate when produced in a country with an entirely different conception of progress and historical destiny than our own? What does a communist Martian Utopia look like, for example, and how did the collapse of the USSR impact the psyche of millions of Soviet children raised with dreams of becoming Cosmonauts? How does Russian medieval past collide with the current Putinist present in recent dystopian novels? This course will explore the origins of science fiction writing in Russia under the Tsar and its flowering under the early Bolshevik regime, who sought to transform fantastic visions of the future into present reality through the promise of the Revolution. We will discuss the intellectual and philosophical novels *Solaris* and *Stalker* by the Strugatsky brothers and their screen adaptations by Andrei Tarkovsky, the mind-bending and scandalous works by Viktor Pelevin and Vladimir Sorokin, and the current popularity of Russian dystopian video games. Students will gain an understanding of the science fiction genre as a whole: how can a work be both realistic and fantastic? What are the boundaries of science fiction, and how is fantasy separated or blurred with reality in a fictional world? The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

82-298 Radicals, Heretics, Hackers: Russian Outlaws in History, Literature, and Film

Spring

The Russian hacker looms large in the global imagination. He's the cyber outlaw sowing confusion and paranoia, the purveyor of fake news and conspiracy theories, the antihero who threatens the interests of powerful people and powerful states, or the state agent who threatens to upend democratic institutions. This course will examine the mythology and reality of "the Russian hacker" by considering this figure in the context of late Soviet and post-Soviet Russian culture. We will attend to the influence of both geopolitical forces, such as the politics of the Cold War, and artistic movements like Postmodernism. The course follows a seminar format. Students will be required to critically analyze literature (Dostoevsky, Bulgakov, Pelevin, Tolstaya), film (Balabanov, Ginzburg), media sources, and scholarship. They will work on written exercises that prepare them to write a research paper to be presented at a research symposium at the end of the semester. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

82-299 Equity & Justice in Modern Languages

Intermittent: 9 units

S23: This course has the dual purpose of examining important human rights issues in Latin America and questioning the role of film in making visible, critiquing, or even sustaining the structures that lead to human rights violations. We will study specific human rights issues tackled by filmmakers in Latin America, such as cultural rights, gender and sexuality rights, economic rights, environmental issues, and war and state terror. Furthermore, we will discuss specific film schools and movements that developed to address human rights and social justice issues in diverse Latin American contexts. Finally, we will look at how Latin American films work the international human rights film festival circuit, and the ethical and practical implications of filming local human rights issues for international audiences. All coursework for this section in English. Students interested in doing coursework in Spanish for Hispanic Studies credit should register under 82-399.

82-300 Language & Society in the Arab World

Fall and Spring: 9 units

Course content varies. Last offered topic: Negotiating Arab Identities and Gender Roles in Film and Literature. This course focuses on the processes of self-definition by Arab men and women in conflict zones in the Middle East and North Africa with relation to national and religious identities, social stratification, sexuality/homosexuality, and gender roles. Students will learn about the social, economic, and political contexts of the films and literary works representing the Maghreb, Egypt, Palestine, Lebanon, Syria, Iraq, the Gulf countries, and Yemen. This course fosters a better understanding of Arab societies and the hybrid identities that negotiate their presence and space within. Students will have the opportunity to engage in a video-conference dialogue with students in the American University in Cairo, Egypt, attend an Arab film during CMU's International Film Festival, and interview native speakers of different Arab countries to further their learning of Arab culture.

82-303 French & Francophone Cultures

Fall and Spring: 9 units

FALL 2023: TBA

Prerequisites: 82-204 or 82-202

82-304 French & Francophone Sociolinguistics

Fall and Spring: 9 units

This course examines the French language in relation to the social and cultural lives of the people who use it across the French-speaking world. To do so, students will explore the links between the French language of all francophones, its use, and the expression of national, cultural, community, and individual identities through the study of diverse texts and data sources, including policy/legal documents, films, music, newscasts, digitized corpuses of spoken and written French, and computer/technology-mediated communication. Through readings, discussions, hands-on activities, and project work, students will 1) develop content knowledge with an emphasis on language ideologies, policy, and planning; language contact and multilingualism; and language variation and change; and 2) develop linguistic skills in French (reading, writing, listening, and speaking) with specific focus on advanced spoken and written expression. This course is repeatable with new topics.

Prerequisite: 82-202

82-305 French in its Social Contexts

Fall and Spring: 9 units

This course is designed to introduce students to how the French is used by its speakers to create meaning in a wide variety of contexts, which in turn are influenced by various variables (e.g., the political and historical circumstances within which French has developed and continues to change, social and geographic variables). To explore these issues, we will create interactive multimedia experiences aimed at being deployed on an interactive video wall and/or in augmented reality settings. If you have experience in French as well as design, film and photography, or computer-science, this is a course for you! Prerequisites: 82-303 and 82-304 or permission of the instructor, Prerequisites: 82-303 and 82-304

82-311 Advanced Arabic I

Fall: 9 units

This course promotes multiple literacies in an integrated approach to Arabic language and culture studies and builds students' ability to function at the Intermediate High/Advanced Low level in a variety of topics. It also embraces the diglossic nature of Arabic by explicitly integrating the teaching of Arabic regional spoken varieties alongside Modern Standard Arabic. Moreover, the course incorporates Computer and other Technology Assisted Language Learning pedagogies to support student learning inside and outside the classroom. The course is aligned with ACTFL's updated Arabic guidelines that perceive the Arabic language as a continuum in which both the regional spoken varieties and Modern Standard Arabic constitute a whole in terms of usage.

Prerequisite: 82-212

82-312 Advanced Arabic II

Spring: 9 units

The course is the continuation of Advanced Arabic I. It continues promoting multiple literacies in an integrated approach to Arabic language and culture studies and builds students' ability to function at the advanced level in a variety of topics. It also embraces the diglossic nature of Arabic by explicitly integrating the teaching of Arabic regional spoken varieties alongside Modern Standard Arabic. Moreover, the course incorporates technology-assisted language learning pedagogies to enhance student learning inside and outside the classroom. The course also implements ACTFL's Arabic guidelines that recognize Arabic as a continuum in which both the regional spoken varieties and Modern Standard Arabic constitute a whole in terms of language use.

Prerequisite: 82-311

82-313 Topics in Modern Arabic Language, Literature and Culture

Fall: 9 units

This course explores definitions of culture and analyzes the dynamic role of language in culture, and culture in language, with an aim to foster cross-cultural awareness and self-realization while developing proficiency in Arabic. Using an integrated approach to the study of the Arabic language, literature, and culture through close readings of current media sources (press, news, magazines, as appropriate), and literary and cultural readings. Additionally, this course is designed to strengthen listening, speaking, reading and writing, within the context of an evolving Arabic culture.

82-314 Literature of the Arabic-speaking World

Intermittent: 9 units

This repeatable introductory course explores the Arab world through a thematic or conceptual focus. In spring 2018, the theme will be 'Diversity in The Arab Culture'. Coursework will include reading short stories and novels to understand the cultural context that gave rise to specific literary works. Students will also continue to develop their abilities to express their ideas both in speaking and in writing, as well as their listening skills in Modern Standard Arabic. There is no prerequisite for this course but it is expected that your language proficiency in the Arabic language is good. **This is a content course in the Arabic language and not an Arabic language course.**

82-320 Contemporary Society in Germany, Austria and Switzerland

Fall: 9 units

This course offers an introduction to contemporary German culture since 1989. Switzerland and Austria will be frequently included in class discussions but the main focus will be on Germany. In the wake of reunification, constructions of German cultural identity have undergone radical changes. Through encounters with articles, literary texts, popular music, and film students will explore these transformations and examine German culture and (both individual and collective) "identities" after reunification. The class sessions will be organized around several thematic segments, including East/West relations during and after reunification, German media, multiculturalism and minorities, and, finally, a segment on how to navigate the business world in German-speaking countries. The course will be conducted entirely in German and is designed to deepen students' understanding and awareness of issues in contemporary German culture.

Prerequisite: 82-222

82-323 Germany, Austria and Switzerland in the 20th Century

Spring: 9 units

This course advances proficiency in communicative and grammatical skills in the German language and knowledge of German-speaking cultures through the study of important events, trends, and people of the twentieth century in Germany, Austria, and Switzerland. Examples will be drawn from literature, newspapers, television, film and other sources. Students will be expected to complete assignments that demonstrate the ability to express critical judgments in both written and oral form, documented through readings and personal research. The course includes a review of the most troublesome points of German grammar.

Prerequisite: 82-222

82-327 The Emergence of the German Speaking World

Intermittent: 9 units

The Italian literary theorist Franco Moretti has written that "Germany is a sort of Magic Stage, where the symbolic antagonisms of European culture achieve a metaphysical intractability, and clash irreconcilably. It is the center and catalyst of the integrated historical system we call Europe." This course is a general introduction to German culture, German history, and German society, with a focus on Germany's role as center and catalyst of the European system. The course is conducted entirely in German. Its goal is to provide students with a basic level of cultural literacy about the German-speaking world. In the course, we will study major trends from the earliest days of German civilization through the middle ages but with primary emphasis on the 18th, 19th and 20th centuries and with a special focus on problems of national, political and cultural identity. Students coming out of the course should have a broad understanding of the various tensions and problems that have characterized German culture and society for the last two centuries. In addition to broadening students' cultural knowledge about the German-speaking world, this course will continue to emphasize the improvement of students' ability to speak, read, write, and listen to German.

Prerequisites: 82-324 or 82-320 or 82-323

82-331 Reading Into a New China I: Population, Youth, Marriage, & Housing

Fall and Spring: 9 units

This 9-unit course is designed for students who have reached the intermediate level of proficiency in the use of Chinese language to develop their language process competency in all four skills to a more advanced level. Students will expand explicit knowledge of socio-cultural influences on Chinese language use, and be able to apply the knowledge to conduct culturally appropriate spoken and written communication across various social domains and genres. Topics to be covered in this class will be closely related to current social issues in China, such as population, youth, love and marriage; marriage and housing. Students will also develop a repertoire of strategies and resources to assist their learning so that they will be gradually becoming autonomous learners who are able to conduct independent learning of the Chinese language, culture, history, and society. Prerequisites: 82-235 or 82-232

82-332 Reading Into a New China II: Transportation, Education, Pop Culture, & Health

Fall and Spring: 9 units

A continuation of Advanced Chinese I, this course is designed to train students' language proficiency in functioning with Chinese in situations beyond their everyday life. Students will continue to learn more complex language phenomena in order to do exposition, explanation, description and argumentation with Chinese. These language phenomena will be introduced to students together with their social and cultural backgrounds through texts and multimedia programs related to various social issues. Classroom discussions and research project presentations will be the major forms of oral practice, and writing practice will mainly focus on essays and research papers. All the discussions and research projects will focus on issues related to traffic, education, employment, pop cultures, healthy living, and other human relations as well as economic situations in China today. Prerequisites: 82-235 Min. grade C or 82-232 Min. grade C

82-333 Chinese Language and Culture

Fall and Spring: 9 units

SECTION A: With China as a growing political and economic power, understanding the country through its history and culture becomes necessary for students as responsible citizens of the world. This course is designed to help students, previously unexposed to Chinese culture and civilization, better understand China's past. By learning about the history of the Middle Kingdom, students will be exposed to the deep and fascinating foundation of Chinese civilization. We will not cover thousands of years of history, but discuss a chronological timeline of dynasties for reference. Areas of focus include the general knowledge of geography, religion, art, ancient lifestyles, and values. This course is conducted in English with no requirement of prior knowledge of Chinese language. SECTION B: This course will introduce students to important developments in China's culture and language since the end of the nineteenth century focusing on the interactions between Chinese and Western cultural traditions and the historical, social, and political contexts in which these interactions evolved. The following questions will motivate discussion: What is Chinese culture in the modern world? What is "modern" and what "traditional" Chinese culture? How does high culture interact with folk culture and popular culture? How have education and language policies shaped Chinese cultural identities over the last century? What does it mean to be Chinese in a diaspora context? This course is conducted in English with no requirement of prior knowledge of Chinese language.

82-334 Structure of Chinese

Fall and Spring: 9 units

This is an upper-level Chinese course for students who have completed the requirements for intermediate Chinese with the goal of enabling students to build up a more comprehensive and systematic understanding of the structure of Chinese so as to lay a solid foundation for the further development of their advanced level language proficiency. This course will cover major complicated structural phenomena in Modern Chinese through the study of specially selected sample texts. Special emphasis will be given to high frequent errors and weaknesses on particularly problematic elements and sentence structures that are common among non-native Chinese speakers. After this course, students can expect to have the ability to use Chinese more accurately and naturally in both speaking and writing on sophisticated topics in life.

Prerequisites: 82-232 or 82-235

82-335 Chinese Culture Through Legends and Folktales

Intermittent: 9 units

This is an upper-level Chinese Reading course for students who have reached intermediate level proficiency in Chinese. It is designed to train students to read extensively in Chinese with fluency and proficiency within a context of rich cultural content. Materials used in this class are selected from traditional fables, mini-stories, and articles from newspapers and magazines on the lifestyle and social changes in modern China. While discussion will be one of the major class activities, students are strongly encouraged to profit from opportunities to build their vocabulary and improve their sense of the Chinese language through reading and writing assignments throughout the semester.

Prerequisite: 82-232

82-337 Mandarin Chinese for Oral Communication I

Fall: 9 units

This course is designed for students who have reached intermediate level in reading and writing Chinese, but have little knowledge of Mandarin Chinese pronunciation, as well as those who aim to further improve their speaking in Chinese. Students will be introduced to Pinyin, the phonetic system of Mandarin Chinese, and work to refine and perfect their speaking skills through special attention to different styles, colloquialisms, and dialectal variations of contemporary spoken Mandarin. Course materials will include authentic Chinese TV programs, documentaries, films, recorded materials, and contemporary literary and non-literary texts. Students will be required to participate in intensive speaking activities, such as interviewing native speakers of Chinese, oral presentations, discussions, debates, and special projects. At the end of the course, students are expected to carry on oral communication with native Mandarin speakers in a clearly participatory fashion on topics related to various social issues in Modern China.

Prerequisites: 82-235 or 82-232

82-338 Mandarin Chinese for Oral Communication II

Spring: 9 units

This course focuses on advanced speaking skills. Class activities include daily reports, presentations, discussions, debates, interviews, description, translation, oral interpretation and oral art performances. These courses also utilize several of websites and online modules. The goal of this courses is to prepare students to feel comfortable and confident speaking Chinese in various settings and to perform various discourse functions (narration, expressing opinions, arguing, etc.) in Mandarin Chinese. In so doing, students will be able to use vocabulary and syntactic patterns that make their Chinese counterpart feel comfortable. Their Chinese counterpart will recognize the students as excellent speakers of Chinese who are knowledgeable about Chinese society and current global issues. Students are expected to be able to deliver good professional presentations in Chinese, perform in culturally-appropriate ways in many different social speaking situations, reach the advanced-mid level of proficiency of the ACTFL national standards, and be able to write a cohesive essay of 800-1000 characters.

Prerequisites: 82-232 or 82-235

82-339 Business Language & Culture in China I

Fall: 9 units

Designed for students who have had at least two years of Chinese language training, this 9-unit course aims to help students enhance their language proficiency in professional environment and develop in-depth understanding of the current business culture in China. Authentic materials from newspapers, magazines, TV shows and online sources will be introduced in class to help students deepen their understanding of the business culture in China. Students will be encouraged to foster creative and independent thinking skills, which are crucial for survival in today's business world, through a variety of classroom activities such as group discussion/debate, professional interviews, business project and presentation, and oral/written business reports. Professional language skills (both in speaking and writing), as well as social and business etiquette, will be also introduced and trained throughout the course.

Prerequisites: 82-235 or 82-232

82-340 Business Language & Culture in China II

Spring: 9 units

Designed for students who have had at least two years of Chinese language training, this 9-unit course aims to help students enhance their language proficiency in professional environment and develop in-depth understanding of the current business culture in China. Authentic materials from newspapers, magazines, TV shows and online sources will be introduced in class to help students deepen their understanding of the business culture in China. Students will be encouraged to foster creative and independent thinking skills, which are crucial for survival in today's business world, through a variety of classroom activities such as group discussion/debate, professional interviews, business project and presentation, and oral/written business reports. Professional language skills (both in speaking and writing), as well as social and business etiquette, will be also introduced and trained throughout the course.

Prerequisites: 82-232 or 82-235

82-342 Spain: Language and Culture

Fall and Spring: 9 units

This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. Spain: Language and Culture focuses on the cultures of Spain, the autonomous regions and the creation of a national identity as a reaction to the multiple ethnicities that have inhabited the peninsula since ancient times. The course advances proficiency in grammatical accuracy, the ability to communicate one's ideas in Spanish, and cultural proficiency. The focus of in-class activities is on written and non-written sources such as history, literature, film, art, and elements of popular culture; the building of reading and writing skills will be complemented by continued oral practice in the form of small and large group discussions and class presentations. Treatment of reading selections is designed to increase students general familiarity with a variety of genres, devices, and discourse types and to build a foundation for the department's more advanced courses in literature, history and culture. The course will be taught in Spanish.

Prerequisites: 82-242 or 82-244

82-343 Latin America Language and Culture

Fall and Spring: 9 units

This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. This course will explore Latin American culture and language, focusing on issues of cultural identity. Tracing the historical thread of the construction of Latin American cultural identity we will distinguish 6 periods organized around crisis when the topic of Who we are? becomes a central debate (Larrain 1996). These periods include: the conquest and colonization, the independence and constitution of nation-states, the inter war period and the depression, the 1970s and the military dictatorships and the present globalization stage. These phases in the development of a Latin American cultural identity represent the existence of certain dominant discourses and controversies that are important in understanding Latin American culture (Larrain 1996). The idea is to explore how Latin America imagines itself and constructs a narrative about its origins and development. There are three main questions we will be exploring throughout the course: Where does the discussion about Latin America emerge from?; How does Latin America think of itself?; What does Latin America want to be?. These questions will be explored historically through readings of philosophical and political texts that deal with Latin American identity as well as with literary texts, films and music that represent practices that enact this/ese identity/ies. The course will be taught in Spanish.

Prerequisites: 82-244 or 82-242

82-344 U.S. Latinos: Language and Culture

Fall and Spring: 9 units

This course is part of the post-intermediate, 300-level program that forms the introduction to the major or minor in Hispanic Studies. Students may begin with any one of the three courses at this level or they may be taken concurrently. This course provides an introduction to and analysis of the cultures and histories of U.S. Latinos. The course will trace the historical trajectories of these groups, both those dating back centuries, such as Mexican-Americans and certain Caribbean populations, and those with more recent, quickly growing populations, such as Salvadoran and Honduran immigrants, in an effort to understand how their identities are forged and transformed over time, considering both internal and external perspectives. Our exploration of U.S. Latino history and cultures will compare and contrast the experiences of people from the above-described categories and analyze the dynamic tension amongst them, with other minority groups, and with the mainstream US society. We will examine a wide variety of materials, including texts, film, art, music etc. in order to gain a better understanding of Latino populations in the United States. Ultimately, we seek to question and to understand the complexities of Latinidad in the 21st century U.S. The course will be taught in Spanish.

Prerequisites: 82-242 or 82-244

82-345 Introduction to Hispanic Literary and Cultural Studies

Fall and Spring: 9 units

This required course is transatlantic, incorporating the study of the cultures of Latinos in the US, Latin American and Spain. Topics vary from semester to semester, aiming to provide a thorough understanding of Latin American, Spanish and U.S. cultures in connection to issues such as race, gender, socio-economic class. FALL 2023: This course explores the politics of gender, identity, sexuality, and health within a transatlantic geographical context. The texts will focus on the 20th and 21st centuries while presenting interdisciplinary perspectives. We will draw on examples from historical debates and documents as well as creative output - all to work toward a synthetic understanding of the following key issues: sexual and reproductive health and rights; sexual autonomy and choice; prostitution; sterilization; eugenics; the right to bear children; abortion; and motherhood. While remaining broad in its scope of the Spanish-speaking world, depth of analysis will be emphasized. We will collectively work together to understand each text, understanding that the methods in which we work to understand feminicide in 21st century Mexico may not be appropriate when analyzing the torture of women during the Spanish Civil War. Therefore, it is understood that no one student, nor professor, will have absolute knowledge of the political, cultural, and historical background of every part of the Spanish-speaking world included in the brief semester of study. The class will be student-centered, and thus highly interactive. It is also a goal of this course to stimulate analytical thinking, and to promote the close readings of texts directed by argumentation and well-structured insights. Students will work collaboratively, with the goal of arriving at their own conclusions about the relationship between representation and reality, experience, and analysis.

Prerequisites: 82-342 and 82-343

82-355 Tpcs in Hispanic Std: Beyond the Film Screen: The Hispanic World Through Film

Intermittent: 9 units

This course is offered only at Carnegie Mellon's campus in Qatar. The purpose of this course is to explore Hispanic culture and history through contemporary films in Spanish. Undoubtedly, films are a rich source of meaningful cultural information that can provide the audience with an understanding of a country's culture (history, politics, social problems, etc.) through their discussion and analysis. Movies not only represent reality, but they do it from a particular position. The images produced in films are charged with political interests that reproduce or challenge established beliefs and views. Films offer different representations of reality as well as different ways of relating to it (Achugar, 2008). We will view and analyze a selected group of films portraying four main issues in Hispanic history and society: memory and oblivion, immigration and exile, marginalized identities throughout history, and the Hispanic world in globalization. An understanding of the socio-political context that these films aim to portray through in-depth reading, analysis, discussion, and investigation will provide a thorough understanding of the complexities of various historic events, and opportunities and challenges faced by the Hispanic world. Throughout the semester, we will practice the four language skills (listening, speaking, reading, and writing) as we continue to build on vocabulary and review grammar points based on the films viewed, the texts read, and the topics discussed.

Prerequisite: 82-242

82-361 Italian Language and Culture I

Fall: 9 units

This is a course in Italian culture and language with a streamlined review of grammar. The course deals with the social, political, economic, demographic, and cultural issues of contemporary Italy. At the same time links are drawn between past and present, evidencing the importance of tradition and history in Italian society.

Prerequisite: 82-262

82-362 Italian Language and Culture II

Spring: 9 units

This is a course in Italian culture and language with a streamlined review of grammar. The course deals with the social, political, economic, demographic, and cultural issues of contemporary Italy. At the same time links are drawn between past and present, evidencing the importance of tradition and history in Italian society. A student with prior experience in Italian must take the Italian placement exam. SPRING 2018: This course traces the development of Italian film from the 1900's silent films to the 21st Century. We will follow a trajectory beginning with the epic tradition of Pastres Cabiria (1914) and Carmine Gallone's Scipio Africans of the Fascist Regime, and continue with study of the Telefoni Bianchi (Art Deco) films of the 30s, neorealism of post-war Italy, the commedia all italiana (Italian style comedy (1950-1970), the humor of Paolo Virzì, the intellectual and artistic concerns of Nanni Moretti, and conclude with Sorrentino's, Il Divo. Students will continue to build their skills in listening, speaking, reading and writing Italian while developing their appreciation of the impact of Italian Film as a cultural and artistic force. The assignments and learning activities which accompany each film provide opportunities for discussion, research, reflection and conversation. The course places emphasis on the historical and cultural situations presented in the films, to help students broaden their background on the history, customs, and geographical representations of Italy. The class will be conducted in Italian.

Prerequisite: 82-262

82-363 Intensive Italian Language & Culture: Advanced Level

Intermittent

No course description provided.

82-371 Changes in Japan I: Food and Work Cultures

Fall: 9 units

This course emphasizes the acquisition of advanced level of communicative language proficiency by immersing students in authentic cultural explorations. The curriculum includes authentic reading texts, multimedia, interviews with native speakers, and viewing and summarizing Japanese films that depict current Japanese society and cultural trends. The course also provides an individualized learning environment throughout the term in improving students' language skills and cultural proficiency. Students may pick a topic of personal interest for their term project thesis. A student with prior experience in Japanese must take the placement exam.

Prerequisite: 82-272

82-372 Advanced Japanese II

Spring: 9 units

This course continues to further improve the acquisition of advanced level communicative language proficiency by immersing students in authentic cultural explorations. The curriculum includes authentic reading texts, multimedia, interviews with native speakers, and viewing and summarizing Japanese films that depict current Japanese society and cultural trends. The course also provides an individualized learning environment throughout the term in improving students' language skills and cultural proficiency. Students may pick a topic of personal interest for their term project thesis. A student with prior experience in Japanese must take the placement exam.

Prerequisite: 82-371

82-373 Structure of the Japanese Language

Fall: 9 units

This course examines the basic Japanese grammar covered in elementary and intermediate Japanese courses by comparison with English and aids students in systematizing their knowledge of Japanese and in deepening their understanding of Japanese culture (i.e., cultural ways of thinking underlying Japanese verbal behaviors). After a brief discussion of the overall typological differences between the two languages and an initial training to analyze them cross-linguistically, it deals with specific areas of grammar that exhibit pervasive structural and semantic differences and serve as exercises for cross-linguistic analysis. On the basis of the discussions and exercises in class, students gather and analyze relevant Japanese data for their project, which facilitates their understanding of the grammar points and cultural ways of thinking in question, and develops their analytical skills. This course is taught in Japanese. A student with prior experience in Japanese must take the placement exam.

Prerequisite: 82-272

82-374 Issues in Japanese Technology & Society

Spring: 9 units

This course seeks to (1) introduce students to technical Japanese or Japanese language used in the field of science and technology, (2) acquaint them with current issues in Japan involving science and technology, and (3) deepen their understanding of the science and technology culture of Japan. It draws on various sources of information such as books, newspapers, video clips, and TV news to familiarize students with current issues in Japan related to science and technology. Through understanding those issues, the course enables them to acquire necessary knowledge of technical Japanese and Japanese cultural perspectives on science and technology. It also requires them to work on an individual project to form and express their own thoughts and opinions on a science and technology issue of personal interest. This course is taught in Japanese. A student with prior experience in Japanese must take the placement exam.
Prerequisite: 82-272

82-376 Intensive Japanese Language & Culture: Advanced Level

Intermittent

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82-380 Multilingual Podcasting: Unlocking Cultural Storytelling

Spring: 9 units

F23: In this course, students will learn about the various characteristics and possibilities of podcasting, and will familiarize themselves with the history, tenets, and examples of cultural storytelling for Spanish-speaking communities using this medium. Likewise, they will get involved hands-on in production learning while creating a series of podcasts that explore the linguistic and cultural landscapes of the local Spanish-speaking community in Pittsburgh, supporting diversity and giving voice to their stories as rich, intimate, and immersive audio experiences. Students will blend studio recordings with interviews and/or suitable "found" recordings, music, and sound. Assigned texts for this course will include primary and secondary sources related to classic examples of community radio such as Radio Venceremos and Radio Rebelde, and episodes from diverse and successful podcasts including Radio Ambulante, Entre Am and #233ricas, and La Brega. We will also engage with materials in which radio and podcasting play a pivotal role. While advancing on Spanish linguistic and cultural proficiency, students will develop research and analytic skills in the target language, learn about the Spanish-speaking community in Pittsburgh, and engage in meaningful interactions with its members. Coursework will include skills development on audio recording and podcasting, production management, creative thinking, materials sourcing, and giving and receiving constructive feedback from classmates and varied audiences on team and individual projects. No previous podcasting experience is necessary, but experience in writing, interviewing, music production, or digital editing would be helpful. Anyone with an interest in podcasting or issues of immigration, bilingualism, and civil rights is encouraged to participate. The course will be taught in Spanish.
Prerequisites: 82-242 Min. grade C or 82-222 Min. grade C or 82-232 Min. grade C or 82-202 Min. grade C or 82-272 Min. grade C

82-382 Introduction to Translation

Spring: 9 units

We will survey a number of different translation theories in order to understand the various approaches that are at our disposal when translating a text. All theory taught in class will be accompanied by hands-on translation projects that will give students the opportunity to try out their knowledge first-hand and evaluate the usefulness of different approaches on a personal basis. In addition, we will explore the profession of translation by researching conferences, forums, websites and associations. Last but not least, we will contact and interview a translator who does translation work we feel particularly passionate about. The course is meant as a general introduction to what it means to be a translator and is open to both undergraduate and graduate students with sufficient knowledge in a foreign language.

82-383 Second Language Acquisition: Theories and Research

Fall: 9 units

This course provides an introduction to research and theories in Second Language Acquisition (SLA). Processes that underlie the learning and use of second languages are examined from four perspectives: 1) as linguistic knowledge, 2) as a cognitive skill, 3) as a personality-mediated process, and 4) a socio-culturally mediated process. Factors examined include: age-related differences, the influence of the first language, the role played by innate (universal) principles, the role of memory processes, attitudes, motivation, personality and cognitive styles, and formal versus naturalistic learning contexts. Issues that arise from the course readings are investigated through practical experience in applying theoretical knowledge to small-scale empirical research projects. Students are also provided with opportunities to consider the relevance of these issues to their own language learning experiences.

82-385 Qualitative methods in SLA research

Fall and Spring

This course provides an overview of qualitative research methodology and techniques. A variety of research approaches will be reviewed and theoretical assumptions and procedural, technical, and ethical issues associated with each will be discussed. Students will have an opportunity to design, implement, analyze, and report a micro qualitative study. Although the focus is on inquiry into second language acquisition, it is intended that the course also be relevant to students in other fields of inquiry.

82-386 Immersive Literary Imaginaries

Intermittent: 6 units

How do we use new immersive technologies to tell stories and share ideas? Can we find ways to express critical and textual analysis through animation, filmmaking, and interactive storytelling? Literature has always found ways to attract new audiences through film and theater adaptations, performances, or talks. Museums and exhibition spaces are increasingly developing interactive displays or immersive installations to explore themes and subjects of important works. Reading together, identifying key themes, and discussing concepts in narrative portrayal and storytelling, we will create short interactive pieces based on critical reflection and textual analysis of a specific literary work. We will write, develop and use immersive storytelling techniques, to share ideas and design user or visitor experiences. You will be guided through technical work while developing your appreciation for the themes and contexts of the novel. This is an applied critical-theory class that blends literature analysis with creative computing and artistic production. Each iteration of this course will be centered on a specific literary work. In spring 2023, we will explore Native American perspectives through contemporary literature, specifically, the novel *There, There* (2019) by Tommy Orange. *There, There* is told through the perspectives of its characters, each bound by history, dealing with their circumstances and each challenging perception of race and identity. Students will adapt and shape critical responses into a series of animated interactive sequences which can be displayed and shared through an interactive book.

82-387 Introduction to Linguistic Data Analysis Using R

Intermittent: 9 units

This course provides a hands-on introduction to the fundamental aspects of statistical analysis of quantitative linguistic data using the open source statistical environment R. The course assumes no prior programming or statistics training. Students will first understand how spoken and written language can be conceptualized as data. Students will learn what this data looks like and how to think about such data from a computational perspective. Students will build a level of confidence in using R that can lead to more advanced programming and statistics classes. Students will also learn how to visualize and appropriately form specific research questions related to linguistic analysis, and how data and its presentation can be manipulated in unethical ways. Students will also examine how the same data set can tell different stories/outcomes depending on the analyses and presentation. In-class labs and homework will make use of corpus, psycholinguistic, and survey data from a variety of languages and methods. At the end of the course, students will be able to select and use appropriate quantitative methods to analyze linguistic phenomena with the help of R. More practically, students will be able to use and understand the R code provided in class and modify it for the purposes of their own research.

82-388 Topics in Second Language Acquisition

Fall and Spring: 9 units

SEC A: This course asks two central questions: 1) How do we capture language learning outcomes that aren't measurable quantitatively? and 2) How do we understand the relationship between context, instruction, and second language learning? To answer these questions, we will examine research and its practical applications from a variety of qualitative traditions (e.g., ethnography, discourse analysis, qualitative interviews, diary studies) that has been carried out in a wide range of contexts, including study abroad, technology-enhanced environments, and informal learning 'in the wild.' SEC B: We will explore how technology can be used and researched in contexts of second language acquisition and teaching. We'll investigate research, best pedagogical practices, and technological tools used in Computer-Assisted Language Learning. Students will learn how to conduct a review of a pedagogical tech tool or app (e.g., Chat GPT, Duolingo, Lingostar AI) and how to integrate it into a task-based or project-based lesson plan. In addition to teaching demos, students will engage in the creation of a research project proposal and/or literature review regarding a specific facet of technology-enhanced language teaching and learning. SEC C: This course provides a hands-on introduction to linguistic data analysis using the programming language R. SEC D: Pragmatics is broadly understood as the study of language use in social context. This course, therefore, addresses various topics in second language (L2) pragmatics, including theories in pragmatics learning, multilingual translanguaging in L2 pragmatics, research methods in L2 pragmatics, target areas of investigation, instruction and assessment, and learning contexts. Through critical examinations of the literature in these areas, students will develop an understanding of existing research paradigms in L2 pragmatics and future directions.

82-390 Soviet Futures: Revolutionary Design

Intermittent: 9 units

This course explores the history of Soviet design from aspirations of an everyday Utopia following the 1917 Revolution to the crumbling facades and "post-Communist aesthetic" of the former USSR today. Students will learn about alternative visions of everyday life and the future from the designers, artists, and theorists themselves, engaging with visual works, historical documents, and manifestos. Class time will also be dedicated to the design theory and philosophy of other 20th century Socialist states such as Yugoslavia and the People's Republic of China.

82-391 Advanced Russian I - Berlin, Paris, New York, Harbin

Intermittent: 9 units

This course investigates the cultural history of the post-Revolutionary Russian emigration to capitals of Europe, North America, and Asia. We will examine the life of Russian and #233;migr and #233; communities in each of these cities, through poetry, literary fiction, memoirs, and diaries. In addition to developing students' cultural awareness, this course aims to advance Russian language learning by expanding students' vocabulary, reinforcing grammatical knowledge, and developing their capacity to speak and write on abstract topics. The readings will be available in English, though students will be encouraged to read the works in Russian. In addition to discussing the texts in Russian, students will complete short weekly homework assignments. **If you would like to take this course, but the current time slot does not work with your schedule please contact the instructor as soon as possible and we may be able to accommodate you** Prerequisites: 82-292 or 82-399

82-392 Advanced Russian II: Great Short Works

Intermittent: 9 units

A ghost robs a poor copy clerk of his prized overcoat. A nightmarish visit to a local museum somehow spirits a Russian refugee back to the Soviet Union. A desperate mother beats her son in order to ensure his bright future. Although Russian literature is famous for its long 19th-century novels, the absurdities of Russian society have been explored no less profoundly in short stories by Gogol, Nabokov, Petrushevskaya, and many others. This seminar examines the Russian short story as a form particularly suited to revealing the barbarism, hilarity, and ecstasy of human experience.

Prerequisite: 82-391

82-394 Russian for Heritage Speakers: Babushka's Russia & Beyond

All Semesters: 9 units

This course is designed to address the linguistic and cultural learning needs of heritage speakers of Russian, those who grew up hearing and speaking Russian at home but who have had little or no formal study of Russian language, culture, or history. Although heritage speakers of Russian often achieve advanced or near-native listening comprehension skills, they require further training in reading, writing, and speaking. Heritage speakers may also be unfamiliar with important aspects of Russian culture key events in Russian and Soviet history, well-known cultural phenomena, literary works, films, and so on and have gaps in their knowledge of social norms. Russian for Heritage Speakers aims to fill these gaps through a combination of grammar instruction and student-led close analysis of texts and audiovisual material. The course is organized around five thematic units that allow students to learn about Russian culture while engaging in interpretive, interpersonal, and presentational modes of communication: "Foundations: Truth and amp; Legends," "Revolutions: Political, Cultural, Social," "Student Life: ' , ' " "Russia in the World," and "Individual and Community."

82-396 The Faust Legend at Home and Abroad

Intermittent

This course introduces students to the basic outlines of the Faust story, and examines its nineteenth- through twenty-first-century manifestations in a variety of European, Russian and American novels, plays, films and operas. On the assumption that cultures reveal something distinctive about themselves by the particular way in which they adapt the legend, this course aims to discover how and why these Faustian works of art respond and contribute to the social, political and historical context in which they are produced. On what is the persistent appeal of the Faust legend based? To what needs does it speak? How does the history of its own, continual reemergence affect the meanings it communicates? Prerequisites: None for 9 units; an additional 3 units, requiring permission of the instructor, can be earned for work done in Russian.

82-397 Radicals, Heretics, Hackers: Russian Outlaws in History, Literature, and Film

Intermittent

The Russian hacker looms large in the global imagination. He's the cyber outlaw sowing confusion and paranoia, the purveyor of fake news and conspiracy theories, the antihero who threatens the interests of powerful people and powerful states, or the state agent who threatens to upend democratic institutions. This course will examine the mythology and reality of "the Russian hacker" by considering this figure in the context of late Soviet and post-Soviet Russian culture. We will attend to the influence of both geopolitical forces, such as the politics of the Cold War, and artistic movements like Postmodernism. The course follows a seminar format. Students will be required to critically analyze literature (Dostoevsky, Bulgakov, Pelevin, Tolstaya), film (Balabanov, Ginzburg), media sources, and scholarship. They will work on written exercises that prepare them to write a research paper to be presented at a research symposium at the end of the semester. No prior knowledge of Russian language or culture is required. The course is conducted in English, but students will have the option to do work in Russian for three extra course units.

82-399 Equity & Justice in Modern Languages (Language-Specific)

Fall and Spring: 9 units

S23: "Derechos Humanos y Cine en Latinoam and #233;rica" This course has the dual purpose of examining important human rights issues in Latin America and questioning the role of film in making visible, critiquing, or even sustaining the structures that lead to human rights violations. We will study specific human rights issues tackled by filmmakers in Latin America, such as cultural rights, gender and sexuality rights, economic rights, environmental issues, and war and state terror. Furthermore, we will discuss specific film schools and movements that developed to address human rights and social justice issues in diverse Latin American contexts. Finally, we will look at how Latin American films work the international human rights film festival circuit, and the ethical and practical implications of filming local human rights issues for international audiences. All coursework for this section in Spanish; may count for Hispanic Studies credit. Students interested in doing coursework in English credit should register under 82-299. (9 units)

Prerequisite: 82-242 Min. grade C

82-400 Russian Studies Topics

Fall and Summer: 6 units

(A1) Literary Culture of the 19th Century Russia (6 Units) The purpose of the course is to give students an introduction to the cultural environment of the Imperial Russia through the works of major 19th century Russian writers. We will read and analyze some masterpieces of Russian fiction, including works of Pushkin, Lermontov, Gogol, Turgenev, Dostoevsky, Tolstoy, and Chekhov. Emphasis will be made on how these brilliant classics reflected turbulent history of the 19th century Russia. (A2) Literary Culture of the 20th Century Russia (6 Units) This mini-course focuses on Russian prose and poetry of the early 20th century. Readings will include the "proletarian" writings of Maxim Gorky, "symbolism" of Alexander Blok, "futurism" and "modernism" of Vladimir Mayakovsky as well as works of some other authors. We will discuss such important issues for 20th century Russian Cultural History as the role of intelligentsia in the Russian Revolution, the content and method of Russian decadence, symbolism, and modernism, as well as imprisonment, liberation, and exile that became so important for many writers and poets.

82-411 Topics in Arabic Media

Fall and Spring

Given the development and spread of new and multi-literacies around us today, the course focuses on reading and analyzing Arabic media sources to engage in discussions about current topics in our modern world. Topics of interest include (but are not limited to): Culture, politics, economy, environment, education, and linguistic diversity. While reading and writing will be mainly in Modern Standard Arabic, class discussions will be of a multidialectal and multilingual nature to encourage questioning, analyzing, and conceptualizing topics in various contexts.

Prerequisite: 82-312

82-412 Topics in Arabic Studies

Spring: 9 units

This course is designed for students who have completed Advanced Arabic. Students will study written, audio, and video material taken from well-known Arabic-language media outlets such as Al-Jazeera, BBC Arabic, al-Arabiyya, etc. Linguistically, this course focuses on Modern Standard Arabic (MSA) because the media is one of the main domains in which MSA is significantly utilized in our modern age. Students will utilize reading, writing, and speaking skills to engage actively in class activities such as group discussions, debates, interviews, short presentations, etc. Students will prepare and present a final project in Arabic to share with the class.

The course can be repeated but after consent of instructor.

82-413 Readings in Islamic History

Fall and Spring: 9 units

This course focuses on Islamic history and enables students to read authentic historical texts in Arabic written three to five centuries ago and to understand the cultural context that gave rise to these texts. Students also will continue to develop their ability to express their ideas both in speaking and in writing and to develop their listening skills in Modern Standard Arabic.

82-415 Topics in French and Francophone Studies

Fall: 9 units

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2023: Paris after 2015: The impacts of the 2015 terrorist attacks on perceptions of the city

Prerequisites: 82-304 Min. grade C and 82-303 Min. grade C

82-416 Topics in French and Francophone Studies

Spring: 9 units

SPRING 2023: Paris, between the Myths and Realities This course will explore the numerous and evolving representations of the Parisian cityscape in literature and popular culture. How do French and foreign authors and filmmakers choose to represent the City of Light? Which aspects of Parisian life do these voices focus on, and why? How do these representations influence French and global perceptions of the city? Drawing from the study of myths by Roland Barthes and Claude L and #233;vi-Strauss, as well as images in poetry, novels, films and popular culture, we will look at the "production" of Paris. We will contrast mainstream images of the city (a place for lovers and baguettes, the Louvre, Notre Dame) with a lesser-known side of the city, from its catacombs to its ethnic neighborhoods and "banlieues." We will also examine the relations between Americans and Paris, from the works of writers such as Ernest Hemingway to the current perceptions of the city conveyed by/in American popular culture. Readings will include Baudelaire's *Le Spleen de Paris*, Victor Hugo's *Les Mis* and #233;rables, Mireille Guiliano's *Ces Fran* and #231;aises qui ne grossissent pas, and Alain Mabanckou's *Bleu Blanc Rouge*. The course will also examine the filmic representations of Paris in Paul Feig's *Bridesmaids* and *Paris je t'aime*. Good reading skills in French and a good ability to express oneself both orally and in writing are essential. In line with the spirit of these explorations, you are encouraged to use a variety of media for your presentation.

Prerequisites: 82-303 and 82-304

82-417 Arabic for the Professions II

Intermittent: 9 units

tba

82-420 The Crucible of Modernity:Vienna 1900

Intermittent: 9 units

Vienna 1900 was many things: the political center of the Austro-Hungarian Empire; the center of German-language music and theater; the birthplace of Zionism and of psychoanalysis; the home of cafe culture and the waltz; the city of baroque urban palaces and squalid backyard tenements; and the showcase for historicism. And while the story of Vienna's cultural and political turmoil is interesting, it probably would not command our attention today were it not for its role as the birthplace of Modernism. The class explores Vienna before the collapse of the Austro-Hungarian Empire in 1918. We will be looking at a huge and at times confusing canvas, which by necessity includes almost every aspect of culture. From history and politics we will move on through art, architecture, psychoanalysis, literature, music, and philosophy. We will be looking at art nouveau buildings and furniture, reading literature, viewing films, and listening to recordings. Using an enhanced historical map of the city as a digital interface and an interactive learning tool, we will add a crucial visual component to the course and research the connections between urban and architectural space and the intellectual activity that took place in it. You will work in teams with students from other disciplines. You will research networks of intellectual and artistic activities and create 3D models of the spaces, from public squares to cafe interiors, in which these intellectual activities took place. You will create and expand a growing collection of records, photos, archival materials, as well as artwork, music and other media in an effort to reconstruct the dialogue among the arts and the cultural debate of this key moment in the passage to Modernism. No previous knowledge of 3D modeling software is required, software instruction and tutoring will be provided. The language of instruction is English with a German credit option

82-425 Topics in German Literature and Culture

Fall: 9 units

This repeatable course explores the culture of the German-speaking nations through a thematic or conceptual focus. Students critically analyze authentic documents, for example, historical, biographical, and literary texts, as well as film and works of the visual arts while improving and expanding their language skills. Fall 2023: Are the Germans funny? Do they have a sense of humor? The answer is yes! U.S. stereotypes of the Germans suggest that they are always serious and negative and never funny. Nothing could be further from the truth! Comedy is actually by far the most popular German film genre, easily surpassing other genres (including historical films and dramas). The Germans love humor. But German humor is very different from humor in the U.S., and it doesn't "travel" across the Atlantic particularly well. This course, conducted entirely in German, will explore at least fourteen very popular post-1989 German film comedies, including *Go Trabi Go* (1991) and *(T)Raumschiff Surprise* Periode 1 (2004), a send-up of the popular U.S. *Star Trek* series. The course will demonstrate that German film comedy is no joke but rather big business! Students will be required to lead one class discussion (in German), to write brief reviews of the relevant films, and to complete a final project, which may take the form of a short paper or a film comedy (in German). Requirements include viewing all the relevant films (outside of class), writing brief reviews of the films, completing occasional required

Prerequisites: 82-320 or 82-323 or 82-327 or 82-426

82-426 Topics in German Literature and Culture

Spring: 9 units

This repeatable course explores the culture of the German-speaking nations through a thematic or conceptual focus. Students critically analyze authentic documents, for example, historical, biographical, and literary texts, as well as film and works of the visual arts while improving and expanding their language skills. SPRING 2023: TBA
Prerequisites: 82-323 or 82-324 or 82-325

82-427 Nazi and Resistance Culture

Spring: 9 units

"How could the land of Goethe and Beethoven also have produced Hitler and the Holocaust?" This is a question that has frequently been posed about Germany. Germany has arguably been the dominant country in Western musical development since the sixteenth century; it has also witnessed an extraordinary flowering of literature, philosophy, and the visual arts. This course, conducted in English, will explore what happened to German culture from 1933 to 1945. In particular, it will examine the Nazi assault on modern (or "degenerate") art and the artistic response of the German and foreign resistance to Nazi tyranny. Arts explored will include literature, film, music, and the visual arts. We will read from the works of a variety of writers, including Öd and #246;n von Horv and #225;th, Anna Seghers, Bertolt Brecht, Adolf Hitler, Albert Speer, Hanns Johst, Joseph Goebbels, and Paul Celan. Film will also play a major role in the course, and students will be required to view (outside of class) and discuss at least seven Nazi-era films, including Veit Harlan's infamous antisemitic Jud S and #252; and #223; and the Nazi film Hitlerjunge Quex (Hitler Youth Quex), about a brave Hitler Youth martyr. CONTENT NOTE: The Nazi regime was racist, antisemitic, misogynist, homophobic, anti-communist, anti-socialist, and antiliberal. The language they used and some of their opponents seldom met the standards of polite speech in the contemporary U.S.A. It is a certainty that students will find the events and attitudes discussed in this course and the language used between 1933-1945 to be offensive and distasteful subject matter. If you feel uncomfortable at any point in the semester, please set up an appointment to meet with the instructor individually. It is important that all members of our community contribute to a safe and positive learning atmosphere.
Prerequisite: 82-327

82-428 History of German Film

Intermittent: 9 units

This course, conducted in English, is a chronological introduction to one of the world's greatest cinema traditions: German cinema. It moves from the silent cinema of the 1910s to the Weimar Republic, when German cinema represented Hollywood's greatest challenger in the international cinema world. It then addresses the cinema of Hitler's so-called "Third Reich," when German cinema dominated European movie theaters, and moves on to the cinema of divided Germany from 1949-1989, when cinema in the socialist east and cinema in the capitalist west developed in very different ways. In the final two weeks of the semester, the course will address German cinema in the post-unification period, which has experienced a revival in popularity and interest. The two historical foci of the semester will be the Weimar Republic, the classic era of German cinema, and the era of the so-called "New German Cinema" of the 1970s and 1980s, when major German directors developed radical new approaches to cinema and critiques of Hollywood. Among the great directors focused on in the course of the semester will be Friedrich Wilhelm Murnau, Fritz Lang, Leni Riefenstahl, Wolfgang Staudte, Werner Herzog, Wim Wenders, and Rainer Werner Fassbinder. No knowledge of the German language is required for this course. Most of the films will be in German with English subtitles. The course will be cross-listed in the departments of Modern Languages, English, and History. Students will be required to attend class, including all film screenings, to actively participate in discussion, to write a term paper on a topic related to German cinema history, and to take two tests.

82-429 German Reading and Translation Workshop: German in Today's World

Intermittent: 9 units

This course will address issues of translation, mostly from German into English, but to a lesser extent also from English into German. It will focus primarily on texts coming from the spheres of current events, politics, economics, and the cultural sphere, but students will also be encouraged to explore and locate texts based on their own interests and concerns. In order to facilitate well-honed translation, it will be necessary to address points of advanced grammar where the structures of the German and English languages feature not only similarities but also differences. The course will thus also constitute a review of issues in German grammar that English speakers may sometimes find particularly challenging. The language of instruction will be primarily German, and students should be comfortable speaking and listening to German. Students will be required to complete a several translation projects, to locate a number of texts from the contemporary German-speaking world that interest them, and to take a midterm and final examination that will focus on translation, issues of advanced grammar, and cultural content.
Prerequisite: 82-324

82-431 China and the West

Intermittent: 9 units

This course takes a look at the multifaceted relationship between China and the Western world from Marco Polo's time to the present. The focus will be on how people in China and the West imagined each other in different times of history and in what ways some historical events and figures, as well as concepts and cultural practices are interpreted differently from Chinese and Western perspectives. Students are expected to reach a deeper understanding of the complexities of cultural interactions and their implications for the diverse world in which we now live. The students will read a rich collection of scholarly writings, and the class will be conducted primarily in discussion format. The class is conducted in English and Chinese. Students will complete readings in both English and Chinese. Assessment will be based on participation in the discussion, student presentations, and written assignments (including research papers, book reviews, and translations).

82-432 Chinese Popular Culture: A Game of Learning

Intermittent: 9 units

S23: There are two reasons why the course is called "A Game of Learning" (and not "A Game of Thrones"): 1. We will be using a video game (i.e. Chinese Parents) as the primary learning resource to explore, discuss, and analyze different aspects of Chinese society and popular culture, such as naming, education, school life and youth culture; 2. We will be using a "gameful learning theory" to design and structure the course, so that all your efforts and accomplishments will earn your precious points (Yes, just like in a game) that help you get your desirable grade at the end of the semester. In other words, with the exception of a few core assignments, you will have the option to complete or not complete all other assignments based on your learning interest and habit. With this power in hand, you can create a unique learning process and a "game ending" that is solely your own.
Prerequisite: 82-332

82-433 Topics in Contemporary Culture of China

Fall: 9 units

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. Prerequisite: 82-332 S20: China has become the second largest economy in the world and is playing a more and more important role in the global society today. To have comprehensive knowledge and in-depth understanding of what has brought about the rapid changes, what is happening there and what to expect for the future is crucial to the professional life of anyone who intends to build up a career in the global community. This 400-level Chinese course aims at helping students obtain knowledge of and develop a deeper and broader understanding of the social, historical, political and cultural situation in China today through the study of materials selected from various media channels, including newspaper and journal articles, films, video clips and other online materials. Students will be able to use Chinese correctly and fluently to introduce, analyze, and comment on various issues in today's Chinese society and make comparisons between contemporary China and its past as well as between China and other countries today. Teaching activities will include classroom discussions and mini-reports. Students' self-reflection essays and semester-end research project will be the major forms of assessment of students' performance.
Prerequisite: 82-332

82-434 Studies in Chinese Traditions

Intermittent: 9 units

Traditional Chinese Thought and Literature through Comic Books Starting from the 1980's, Tsai Chih Chung (a master cartoonist in Taiwan) created a series of comic books illustrating canonical works in traditional Chinese philosophy and literature. The series soon became a great hit both in Taiwan and China, and has since been translated into different languages around the world. While its popularity continues to grow among its readers, its wide circulation also raises questions among scholars and critics of traditional Chinese literature and culture. In this course, students will be asked to read Tsai Chih Chung's comic books and their animated adaptations, the English translations of the Chinese canonical texts of philosophy and literature, and the secondary sources that provide historical and analytical introductions to the texts. While enjoying Tsai's innovative and delightful comic interpretation, students will work in Chinese to consider serious philosophical questions along with the early Chinese thinkers, to learn to savor the aesthetic beauty of traditional Chinese literature, and to prepare to share their ideas and discovery with the rest of the class.

Prerequisite: 82-332

82-436 Introduction to Classical Chinese

Intermittent: 9 units

Classical Chinese is a language shaped in the latter half of the first millennium B.C. that still persists as a living medium of expression today. Knowledge of Classical Chinese is very important to help students read and understand sophisticated modern Chinese texts, which make frequent use of Classical allusions and constructs. Moreover, the cultural values expressed in the ancient texts have played an important role in shaping Chinese families, culture and society. The main goal of the course is for students to promote their skill in reading Classical Chinese and their knowledge and understanding of ancient Chinese culture, society and history. With this knowledge and training, not only will students be more comfortable reading the Chinese Classics, they will also thereby increase their proficiency in modern Chinese and their knowledge of Chinese culture.

Prerequisites: 82-332 or 82-338 or 82-337

82-439 Modern China Through Literature

Intermittent

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills.

82-440 Studies in Chinese Literature & Culture

Fall: 9 units

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2021 This course will begin by showcasing some Chinese folk performance art traditions including hand puppet, shadow puppet, and string puppet performances, and regional opera performances, and investigating their relationships with Chinese folk beliefs and temple festivals. Next we will investigate more modern pop culture artifacts such as pop songs and films. Through these investigations students will explore the culture of both traditional and modern performing arts, their relationship with Chinese local culture and societies, and their national and global impact. Class activities will include showcases of media and printed materials, lectures and discussion, as well as presentation of multimedia examples of these representative performing arts and pop culture.

Prerequisite: 82-332

82-441 Studies in Peninsular Literature and Culture

Intermittent: 9 units

This repeatable course explores the cultures of Spain through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2023: Bodies in/of Representation: Gender, Identity, Sexuality, and Health This course explores the politics of gender, identity, sexuality, and health in 20th and 21st century Spain from interdisciplinary perspectives. There will be a central focus on texts including film, novel, essay, painting, and photography. We will draw on examples from historical debates and documents as well as creative output -all in order to work toward a synthetic understanding of the following key issues: sexual and reproductive health and rights; sexual autonomy and choice; prostitution; sterilization; eugenics; the right to bear children; abortion; and motherhood. Students will work collaboratively in the target language with the goal of arriving at their own conclusions about the relationship between representation and reality, experience and analysis. This course is taught entirely in Spanish.

Prerequisite: 82-345

82-443 Spanish Reading and Translation Workshop

Intermittent: 9 units

This course is of interest to advanced Spanish majors and minors as well as other native or heritage speaker non-specialists seeking to develop translation skills from English-Spanish and Spanish-English. It provides students with an introduction to basic concepts, theories, and techniques of translation, and helps them develop a systematic approach to resolving language transference problems. Students will deepen their understanding of Spanish and English as they consider how best to translate structures, words, text, and discourse styles unique to each respective language while simultaneously acquiring a valuable and highly marketable skill. This course is conducted in Spanish. *Prerequisites: 82-345 or permission of instructor. Prerequisites: 82-345 or 82-344 or 82-343 or 82-342

82-444 The Structure of Spanish

Intermittent: 6 units

This course will provide students with a theoretical framework and analytic tools to investigate how Spanish speakers represent, construct, and transform their social worlds. In particular, the focus is on language as a social practice through which power relations are maintained or challenged. Using a variety of spoken and written texts, the course seeks to analyze to explore the discourse-semantic and lexico-grammatical features that Spanish users deploy to make meanings and negotiate understandings. This analysis will later be interpreted from an interdisciplinary perspective drawing on social theory and history. FALL 2017: This course is an advanced introduction-in Spanish-to contemporary "print," digital and visual media from North, Central and amp; South America, and the Caribbean, and how "information" and "opinion" produce, disseminate, and communicate specific messages. We will review and analyze the rhetorical and visual toolse.g., style, tone, perspective, purpose, exaggeration, distortion, symbolism, labels, irony, and allusionthese texts deploy to determine their role in meaning making for readers and viewers. A primary goal for this course is for students to develop and sharpen the skills necessary to determine reliability in information sources, and hone their ability to write and talk about this.

Prerequisite: 82-345

82-445 U.S. Latino Literature

Intermittent: 9 units

This course proposes to problematize socio-political and historico-cultural issues concerning U.S. Latinos and Hispanic immigrants in the United States. This will involve the analysis and application of assimilation, transculturation and bilingualism theory, and rhetorical/translational problematics of the material under examination. Also of interest will be an ongoing class discussion of Latinos/Hispanics in history, the media, entertainment, politics, and education. Students will consider the question of the "borders," geographical, political and societal, that may or do exist between U.S. mainstream society, Latinos and Hispanic immigrants, and strategies employed by hyphenated-Americans for overcoming, subverting or undermining this situation. Materials for the course will include literature, film, essays, and music by and about Latinos and Hispanics in the United States. FALL 2023: Mapping Dreams and Nightmares: Seeing and Writing the US-Mexico Border This course will focus on the US-Mexico border, with particular emphasis on visual representations of the border from both the US and Mexico, and on the unique, vibrant frontera cultures that result in the space betwixt and between. The course will emphasize key moments and events in the history of the border, including for example the Mexican Revolution, the creation of the border patrol in the 1920s, the Bracero program, Operation Wetback, the Chicano movement, Operation Gatekeeper, and will consider how visual and textual representations have responded to and been conditioned by the political and economic relationship between the US and Mexico, particularly in the wake of neoliberal policies. We will draw on a wide variety of materials, including film, video, visual arts, performance, border theory, and literary and journalistic texts.

Prerequisite: 82-345

82-448 Topics in Arabic Language, Literature, & Culture

Intermittent: 9 units

This repeatable course explores the Arab world through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills.

Prerequisite: 82-312

82-449 Arabic Sociolinguistics

Intermittent: 9 units

This course focuses on the main concepts in sociolinguistics such as diglossia, dialects, variation, gender, etc. These concepts then are applied to the Arabic language in particular. We will read selected chapters from the assigned book that deal with these concepts in general, and then we will read other assigned articles that apply these concepts to the Arabic language. This course explains the historical and existing linguistic repertoire in the Arab countries.

82-450 Advanced Research in Hispanic Language & Culture

Fall and Spring: 9 units

This course permits in-depth, 400-level study in the following courses: 82-342 Spain: Language and Culture, 82-343 Latin America: Language and Culture, and 82-344 U.S. Latinos: Language and Culture. Students will meet with the regularly scheduled 300-level class, read additional texts, and produce research assignments as agreed upon by the instructor and student. The focus is on a deeper understanding and individualized research of the course topics. Prerequisite: Permission of instructor

82-451 Studies in Latin American Literature and Culture

Intermittent: 9 units

This repeatable course explores cultures of Latin America through thematic or conceptual focus. Students analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2022: Revolution, Desire and Disenchantment - Cuba and Nicaragua 2019 marked 60 years since the Cuban Revolution, touted as the victory of a tiny island over US imperialism, and 40 years since the triumph of the Sandinistas in Nicaragua, the movement coming to power when revolutionary struggles in other Central American nations fell short. Both garnered broad international attention due to their importance in the Cold War; they served as symbolic inspiration and real support to movements around the world, and as such, were idealized by the Left and vilified by the Right. While different, the Cuban and Nicaraguan Revolutions shared an understanding of the value of capturing the public imaginary through the arts. This course will interrogate the relationships between political and artistic movements. Once these political movements triumphed, how did artists negotiate the institutionalization of revolution? How did the role of prominent cultural workers evolve? Criticism of these revolutionary movements is not new, but scrutiny has been particularly intense recently, as journalists, artists and political dissidents have faced harsh reprisals, out migration increases, and protest movements grow. In this context of crisis, we will question the dynamic between artists whose works express discontent and the State: what is the space for dissent? How do artists of newer generations create space for types of expression that diverge from what early revolutionary moments considered transformative? Decades later with deeply entrenched governments, what is the relationship between the arts and socio-political change?

Prerequisite: 82-345

82-455 Topics in Hispanic Studies

Fall: 9 units

This repeatable course explores Spanish-speaking cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. FALL 2023: TBA

Prerequisite: 82-345

82-456 Topics in Hispanic Studies

Spring: 9 units

This repeatable course explores Spanish-speaking cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills. SPRING 2017: Southern Cone Dictatorships in the Movies (1984-2016) This course explores the Southern Cone dictatorships during the period of the Cold War through their representation in films. The military-civilian dictatorships of the 1970s in Argentina, Chile and Uruguay were a period of State terrorism. This violent period resulted in thousands of disappeared people, political prisoners and exiles. These experiences have had a lasting impact in the new democracies. There is still a debate over how to address violations of human rights and how to make sense of the past, so that these events don't happen again. There has been a rich production of movies focusing on this historical period that serves as a document of how the struggles over how to come to terms with a traumatic past have been dealt with by different countries. These films also provide a glimpse of how popular culture serves as a vehicle to construct a social memory of recent history. Through films new generations that did not experience these traumatic events learn about what happened and what it means for particular social actors. We will analyze films from Argentina, Chile and Uruguay in order to better understand how these countries have dealt with a contested past. The course will provide students with historical background, theoretical frameworks and analytic tools to approach these cultural productions as documents and discourses about the recent dictatorships.

Prerequisite: 82-345

82-473 Topics in Japanese Studies

Fall: 9 units

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, cultural, social, historical, biographical, filmic, artistic, literary, musical, linguistic, and theoretical perspectives, while improving and expanding their language skills. F23: This course analyzes postwar Japan's subculture as a creative force that is vital to its counter-discourses against the dominant ones in the mainstream. Ubiquitous and often volatile, various forms of the subculture have emerged in critical junctures of postwar Japanese society and culture, from the Occupation (1945-1952), to the Americanization in the 1950s, to the Japanese version of the student movement in the 1960s, to numerous trends out of the economic euphoria in the 1970s-1980s. Collectively those various forms of Japan's subculture foreshadow the essential components of contemporary Japan's popular culture and changing social norms. Taught in Japanese.

Prerequisite: 82-372

82-474 Topics in Japanese Studies

Spring: 9 units

This repeatable course explores target cultures through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, cultural, social, historical, biographical, filmic, artistic, literary, musical, linguistic, and theoretical perspectives, while improving and expanding their language skills. SPRING 2023: This course analyzes various aspects of Japan's urban culture, the evolution of which has centered around Tokyo, focusing on a main question: how Japanese culture has reinvented itself, particularly between the first Tokyo Olympics (1964) and the second (2021). With this question in mind, the course also extends to such topics as the post-WWII Americanization of Japanese culture and society, the cultures in the 1980s as antecedents to the popular and subculture that have continued to thrive on a global scale (e.g., otaku and the aesthetics of superflat), through fictions, non-fictions, films, and multimedia. Taught in Japanese.

Prerequisite: 82-372 Min. grade C

82-480 Translation Technologies

Intermittent: 9 units

This course is designed to give students conceptual and practical knowledge of language translation technologies, as well as applied skills for use with common Computer Assisted Translation (CAT) tools. Students will have the opportunity to work directly with CAT tools and engage in meaningful discussion of the benefits and limitations of Machine Translation, Translation Management Systems, and Translation Memory, among others. Students will focus on acquiring technical CAT skills and developing independence, on terminology management, and on translation technology functionality while taking into consideration the ethical, historical and occupational considerations surrounding the use of translation technologies.

82-481 Translation Workshop 1

Spring: 9 units

This course examines the practice of applied translation in a variety of linguistic and cultural domains. We will explore key concepts such as relevance, equivalence, back-translation, and translation as a social transaction, and engage in the practical application of theoretical approaches to a variety of text types with different purposes and for different audiences. In applied translation, the translators task is a process that can be defined as repurposing a text in another language for a functional use. Foremost in this process is preserving the integrity of the information being communicated, the appropriate context for the task. Students will further develop and refine their practical translation skills and apply them to examples from specialized domains such as health care, public affairs, business, marketing, journalism, mass media, literature, and others. In addition, students will gain familiarity with textual conventions that govern source and target texts within these domains and deepen their understanding of both L1 and L2 as languages for special purposes. To achieve this, students will analyze texts for register, style, tone, and content to determine the most appropriate process to achieve the highest quality translation, and also explore and utilize translation resources available to them as well as create their own, domain-specific resource kits. All students will complete a semester-long series of graded L1 and L2 and L2 and L1 assignments. Additionally, when assignments involve translation of texts into English, students will also be working in collaboration with faculty members in those languages. Students will maintain a translation portfolio throughout the semester. In it they will archive all portfolio assignments (drafts and rewrites), document their progress through the course (regular assignments, remedial assignments, a log of projects, due dates, turn in dates, and grades, etc.).

82-482 Introduction to Translation

Intermittent: 9 units

We will survey a number of different translation theories in order to understand the various approaches that are at our disposal when translating a text. All theory taught in class will be accompanied by hands-on translation projects that will give students the opportunity to try out their knowledge first-hand and evaluate the usefulness of different approaches on a personal basis. In addition, we will explore the profession of translation by researching conferences, forums, websites and associations. Last but not least, we will contact and interview a translator who does translation work we feel particularly passionate about. The course is meant as a general introduction to what it means to be a translator and is open to both undergraduate and graduate students with sufficient proficiency in a language other than English.

Prerequisites: 82-320 or 82-373 or 82-340 or 82-394 or 82-391 or 82-372 or 82-311 or 82-303 or 82-304 or 82-331 or 82-332 or 82-342 or 82-343 or 82-344 or 82-345 or 82-323 or 82-371

82-483 Translation as a Profession I

Intermittent: 3 units

We will learn from professionals in the field of translation. Every class will feature a guest speaker from the Pittsburgh area and beyond who will present his or her own educational background, experience in the field and current relation to the translation industry. Students will meet a variety of professionals, learn about the field, and establish valuable connections for the future. The course is open to anyone interested in the field of translation, both undergraduate and graduate students.

82-489 Service Learning in the Community

Intermittent

This is a community-based research (CBR) course for advanced students who wish to bridge service and action research. The course provides an experiential component that allows students to use their second language and culture skills while acquiring or honing their research skills. CBR helps bridge the gap between university and community life to facilitate the development of life-long learning habits and humanistic citizenship. ML students and faculty will jointly design and execute ways in which to "give back" to the community being studied, which will be chosen based upon the language, culture and/or history of a specific community. Students in this course may participate in historical, ethnographic and cultural research; ethnographic fieldwork; problem solving activities around a particular issue the community is facing; discover how to best identify a particular linguistic/cultural community and document, interpret, preserve and disseminate its history and culture. Class activities may include group, pair and independent reading and research; group and pair travel; group, pair and one-on-one interaction with community members; public presentations; photography, filming, scanning; webpage and document design; and different kinds of writing. Prerequisite: Completion of all 300-level coursework, or an approved equivalent, or permission of instructor

82-492 The Historical Imagination in Nineteenth-Century Russian Literature

Intermittent

Pushkin, Gogol, Lermontov, Turgenev, Dostoevsky and Tolstoy all ruminated upon their nation's historical destiny. This course aims to describe the role played by imagination in these authors' efforts to break from Russia's past a vision of her future. Emphasis is placed upon the figurative operations of language that allow narrative to function as a guidepost to a collective mission and a map of the individual's location within the projected historical scheme. Lecture and discussion formats are combined at each class meeting. Written papers, oral presentations, and participation in discussions are required. Prerequisites: None for 9 units; an additional 3 units, requiring permission of the instructor, can be earned for work done in Russian.

82-495 Topics in Applied Second Language Acquisition

Intermittent: 9 units

SPRING 2016: Section A: Teaching Chinese as a Foreign Language This course aims to expose students to current professional practices and common situations related to teaching Chinese as a Foreign Language (CFL). It will provide an overview of CFL research, teaching and learning with demonstrations of CFL pedagogical issues, applications and solutions. It is intended to help students become familiar with specific CFL issues concerning the special characteristics of the Chinese language, including tones, a character-based writing system, and special Chinese grammatical structures. Students will be able to apply course material to their CFL teaching and research, and feel more comfortable and adaptable in their CFL professional careers. Section B: Issues in TESOL In this course, students will receive a broad overview of current topics that will introduce them to the pedagogic and sociocultural issues that Teachers of English to Speakers of Other Languages (TESOL) instructors encounter in classrooms today, in a variety of contexts. Students will be required to familiarize themselves with and be prepared to address issues in TESOL classrooms. These issues include but are not limited to methodology, teacher education, the role of culture and intercultural communication, and specific challenges in diverse settings, such as modifying course content to focus on academic language. The course will be conducted as a seminar with students completing readings outside class time and discussing the topics and perspectives during class time. Students will engage in reflection through class discussions and electronic discussion forums. The main assignments for the course will be case histories of diverse populations of students who are found in TESOL classrooms, and a final research paper. Students will gain in-depth knowledge of the state of the art in TESOL today.

82-499 Alternative Break Project (Language Specific)

Intermittent

This course provides advanced ML language students and non-ML students enrolled in an Alternative Break student trip project the opportunity to earn credit by engaging in "connected" modes of knowing, by identifying and analyzing a problem, and developing plans for short-term and sustainable solutions, reflecting, and creating and disseminating an informational and interpretive website and print materials about their experience. Students will also bring to bear or gain experience in non-academic skills/talents/interests in areas like photography, image editing, video production, writing, design, website development, sound recording, and art, etc., by doing community service under the auspices of Carnegie Mellon University's Alternative Break program. Students will earn three (3) units for full participation and fulfillment of course requirements. With the approval of the faculty facilitator, an additional three (3) units may be earned by completing an additional assignment.

82-501 Special Topics in French & Francophone Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in French and Francophone Studies involving group or individual study in a subject area approved by the instructor.

82-502 Special Topics in French & Francophone Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in French and Francophone Studies involving group or individual study in a subject area approved by the instructor.

82-505 Modern Languages Undergraduate Internship

Intermittent

To be eligible for the ML Internship, you'd need to find an internship where the use of your language of study will be a large part of your working for an organization. Internships are supervised work experiences either on or off campus and are related to your academic interests and career goals. To earn academic credit, you must arrange a Modern Languages faculty sponsor who agrees to define the academic component of your work, monitor your progress, and assign a final grade. You also need to have a work site supervisor willing to communicate with the faculty sponsor and provide an evaluation of your work before a final grade is assigned. Modern Languages internships will be graded on a pass/fail basis only. Units for the class will be contingent upon how much of your language of study will be a part of your day-to-day work. If approved to participate in the internship: You must maintain regular contact with your faculty sponsor as agreed to at the beginning of the internship. In addition to any required written assignments, upon completion (but before grades are due) you must submit a reflective evaluation of your internship experience to the faculty sponsor. Additionally, students are responsible to see that site supervisors submit a brief written evaluation of the student's internship to the faculty sponsor before the grade is entered.

82-506 Hispanic Studies Internship

Fall and Spring

Pre-approved, advanced Hispanic Studies majors may receive credit in connection with volunteer or paid work experience (usually in Pittsburgh) in which they primarily or significantly use their target language outside the traditional classroom setting. As a rule, this experience takes the form of work involving language use or research at off-campus sites or in the Department. Work or research must be done using the language of study. For off-campus internships, there must be an on-site supervisor available to collaborate with the faculty advisor in the ongoing and final evaluation of the student's work and progress. Students will be required to write and submit reflexive projects, as determined by the faculty advisor, that evaluate the non-classroom experience in the context of the language- and cultural-learning experience and several other criteria that show how the internship connects back to the student's academic or professional education. Prerequisite: Students must be advanced Hispanic Studies majors and obtain prior permission for the proposed work from a Hispanic Studies advisor and/or the Modern Languages internship advisor.

82-511 Special Topics in Arabic Studies

Fall: 9 units

This repeatable course explores the Arabic language and culture through a thematic or conceptual focus. Students critically analyze authentic documents through, for example, historical, biographical, filmic, artistic, literary, musical, and theoretical perspectives, while improving and expanding their language skills.

82-512 Special Topics in Arabic Studies: Advanced Grammar Workshop

Spring

This class is for advanced students interested in explicit, focused instruction on Modern Standard Arabic (MSA) grammar. The class is organized as a workshop around grammar topics that students identify as of interest to them, and includes grammar explanations and practice through writing and giving presentations to demonstrate their understanding of covered topics. This course is taught in Arabic (MSA) and is repeatable.

82-521 Special Topics in German Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in German Studies involving group or individual study in a subject area approved by the instructor.

82-522 Special Topics in German Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in German Studies involving group or individual study in a subject area approved by the instructor.

82-531 Special Topics in Chinese Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in Chinese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of instructor and a 400-level course
Prerequisites: 82-436 Min. grade C or 82-434 Min. grade C or 82-440 Min. grade C or 82-433 Min. grade C

82-532 Special Topics in Chinese Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in Chinese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of instructor and a 400-level course

82-533 Cultural Topics in Chinese Studies

Fall: 6 units

FALL 2022: The Pursuit of Happiness in Early Chinese Thoughts and Their Modern-day Applications (section taught in English): Do you claim to be a happy person? If so, why? If not, why not? How do we define "good life" and where can we get it? This course will inspect various responses to these questions in early Chinese thoughts and their modern-day applications from a global perspective. Chinese thoughts and philosophy are the intellectual foundations of Chinese culture throughout history. They represent the love and pursuit of wisdom in Chinese tradition. The course will explore some major schools of thought in early China such as Daoism/Taoism, Confucianism, Buddhism, Legalism, and Mohism, and look at the manifestations of their wisdom in various aspects of contemporary Chinese society, including food, medicine, Fengshui, architecture, painting, calligraphy, and Taichi. This course will be taught in both English and Chinese, with two weekly meetings conducted in Chinese and English respectively and asynchronous assignments and/or small group meetings. Students can opt to attend only the English meetings for 6 units (82230), only the Chinese meetings for 6 units, or both for 12 units (highly advanced or near-native Chinese proficiency required). To promote intercultural communications, the course welcomes participation of native Chinese speakers for cross-cultural peer learning.

Prerequisites: 82-433 Min. grade C and 82-434 Min. grade C

82-541 Special Topics in Hispanic Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in Hispanic Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-542 Special Topics in Hispanic Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in Hispanic Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-561 Special Topics: Italian Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in Italian Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-562 Special Topics: Italian Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in Italian Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-571 Special Topics in Japanese Studies

Fall

Restricted to language majors who wish to go beyond the regular course offerings in Japanese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-572 Special Topics in Japanese Studies

Spring

Restricted to language majors who wish to go beyond the regular course offerings in Japanese Studies involving group or individual study in a subject area approved by the instructor. Prerequisites: Permission of the instructor and a 400-level course

82-580 Senior Seminar in Modern Languages

Spring: 9 units

This seminar for majors in Modern Languages focuses on general issues in second language learning. It provides an integrative and culminating experience for students as they complete their studies. The course includes consideration of language learning and language maintenance, the role of second languages in American life, issues of linguistic and cultural diversity in the United States today and discussions of multiculturalism throughout the world. The goal of the seminar is for students to reflect upon their language learning experience and to discuss the role that a second language plays in their own lives and in American society today. Corequisite: Open only to Modern Languages majors

82-585 Topics in Second Language Acquisition

Intermittent: 9 units

This repeatable course promotes inquiry into issues related to second language acquisition, for example, use of technology in language learning, language variation, code-switching, pragmatics, sociocultural theory. Students will engage in research and project work and employ qualitative and/or quantitative research methodology and analytical and/or empirical methods to illuminate and understand the acquisition, use, and maintenance of second languages. Prerequisite: Permission of instructor
SPRING 2016 Section B: East Asian Psycholinguistics Our understanding of cognitive processes and mechanisms underlying language has primarily come from studies of European languages. However, languages such as Chinese, Japanese and Korean offer profound implications for the acquisition, representation, and processing of language, due to their differences from most European languages. Topics include first and second language acquisition, spoken word recognition, reading, language disorders, and the relationships between language, culture, and cognition. This course serves to prepare students for more advanced studies of East Asian languages, experimental linguistics, and linguistic theory.

82-591 Modern Languages Honors Thesis

Fall: 9 units

Modern Languages majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of an individual faculty member. Students and faculty select the research topics. Prerequisites: Senior standing; a 3.5 QPA in one's language major; a 3.25 QPA overall; permission of the Department Head and approved entry into the College's Honors Program

82-592 Modern Languages Honors Thesis

Spring: 9 units

Modern Languages majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of an individual faculty member. Students and faculty select the research topics. Prerequisites: Senior standing; a 3.5 QPA in one's language major; a 3.25 QPA overall; permission of the Department Head and approved entry into the College's Honors Program

82-599 Russian Studies Thesis

Intermittent

The Russian Studies thesis, as described for the Russian Studies major, is required of all Russian Studies majors and consists of researching and writing a thesis employing both Russian-language and English-language sources, and generally completed during the senior year. Work is done individually under the guidance of a Russian Studies advisor.

Department of Philosophy

Peter Sprites, Department Head

Location: Baker Hall
www.cmu.edu/dietrich/philosophy (<http://www.cmu.edu/dietrich/philosophy/>)

The Department of Philosophy was founded in 1985 and reflects the tradition of philosophy as a central discipline in the humanities. The department has achieved an international reputation through the acclaimed research of its members and its innovative educational programs, not only in traditional topics such as ethics, philosophy of mind, logic, and theory of knowledge, but in such contemporary and applied areas as automated theorem proving, machine learning, the foundations of statistics, causal discovery, forward learning theory, game and decision theory, conflict resolution, and business ethics.

Philosophy thrives through contact with other disciplines. Interdisciplinary work, a traditional strength of the Carnegie Mellon community, is vital to the department and is reflected in the courses we offer, many of which incorporate substantive material from a range of other disciplines. Some courses are actually team-taught with professors from other departments and schools around the university.

Our programs are designed to develop our students' analytical sophistication and their practical and theoretical skills in specializations outside the department (see the sample curricula below). The department welcomes and, indeed, encourages minors and additional majors from other disciplines who are interested in reflecting on the foundation of their own subjects. The department offers three different undergraduate major programs, and jointly sponsors an interdepartmental major: Ethics, History, and Public Policy (with the Department of History):

- the B.A. or B.S. in Ethics, History, and Public Policy (interdisciplinary major with Department of History)
- the B.S. in Logic and Computation
- the B.A. in Philosophy
- the B.A. in Linguistics

The major in Logic and Computation is perhaps the most non-traditional of the department's majors. It offers students a firm background in computer science, together with a solid grounding in logic, philosophy, and mathematics. This reflects the department's commitment to the use of formal, analytic methods in addressing philosophical issues. A flexible system of electives allows students to focus their efforts in any of a wide range of disciplines, from engineering to the fine arts. As a capstone to the program, students engage in original research in their senior year, and write a thesis under the direction of an advisor.

The department also sponsors six minor programs:

- the minor in Ethics
- the minor in Linguistics
- the minor in Logic and Computation
- the minor in Philosophy
- the minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC)
- the minor in Societal & Human Impacts of Future Technologies (SHIFT)

Finally, the department offers two master's programs directly extending the departmental majors. Both programs are coordinated with and build on the undergraduate programs, so that majors can complete the requirements for the master's degree in one additional year:

- the M.S. in Logic and Computation
- the M.A. in Philosophy

The Major in Ethics, History, and Public Policy

Professor Steven Schlossman, *Director of Ethics, History, and Public Policy*, History Department
Location: Baker Hall 236A, 412-268-2880
sls@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

Patrick Doyle, *Academic Program Manager*, Philosophy Department
Location: Baker Hall 161G, 412-268-3704
pdoyle2@andrew.cmu.edu
<https://go.oncehub.com/PatDoyle/>

The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy 18 units

Choose one of the following two courses:

| | | |
|--------|---|---|
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |

Choose one of the following two courses:

| | | |
|--------|------------------------|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-330 | Ethical Theory | 9 |

II. Ethics and Policy Core 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

| | | |
|--------|--|---|
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |

| | | |
|--------|---|---|
| 80-245 | Medical Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

III. History and Policy Core 36 units

Choose four of the courses below:

| | | |
|--------|--|---|
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-204 | American Environmental History | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-234 | Technology and Society | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 70-332 | Business, Society and Ethics | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

| | | |
|--------|-------------------------------------|----|
| 79-449 | EHPP Capstone Course [cross-listed] | 12 |
|--------|-------------------------------------|----|

| | | |
|--------|-------------------------------------|----|
| 80-449 | EHPP Capstone Course [cross-listed] | 12 |
|--------|-------------------------------------|----|

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

| | | |
|-----------|--|----|
| 21-257 | Models and Methods for Optimization | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 70-208 | Regression Analysis | |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 70-257 | Optimization for Business | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-251 | Empirical Research Methods | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

| Third-Year | | Fourth-Year | |
|----------------------------------|---|--------------------------------|--------------------------------|
| Fall | Spring | Fall | Spring |
| Foundations Course in History | Foundations Course in Law and Social Sciences | EHPP Capstone Course | Ethics and Policy Core Course |
| Foundations Course in Philosophy | Foundations Course in Law and Social Sciences | Ethics and Policy Core Course | History and Policy Core Course |
| Ethics and Policy Core Course | Ethics and Policy Core Course | History and Policy Core Course | Third Course (open) |
| History and Policy Core Course | History and Policy Core Course | Fourth Course (open) | Fourth Course (open) |
| Fifth Course Open | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Major in Linguistics

Patrick Doyle, *Academic Program Manager*

Location: Baker Hall 161G

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Linguistics is the scientific study of human language. The central goal of the Linguistics Major is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Major is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning.

The **Core courses** cover the principal domains of linguistic analysis: phonetics and phonology, syntax and meaning.

Students then move on to the **Extended Core**, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. These courses are supplemented by a wide-ranging set of electives including linguistically relevant courses taught in other departments.

Primary majors complete their course of study with a Senior Thesis, a semester-long research project carried out independently with one-on-one guidance from a member of the linguistics faculty.

Curriculum

The Linguistics **primary major** requires a total of 12 courses plus a senior thesis. The Linguistics **additional major** requires a total of 13 courses (senior thesis not required). This includes 2 semesters of sequential language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

| | | |
|-----------|---------------------------|---|
| 80-180 | Nature of Language | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-280 | Linguistic Analysis | 9 |
| or 80-285 | Natural Language Syntax | |
| 80-381 | Meaning in Language | 9 |
| or 80-383 | Language in Use | |

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

| | | |
|--------|---|---|
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |

LANGUAGE REQUIREMENT

Students must successfully complete 2 semesters of foreign language study in a single language (e.g. 100 & 200 level).

Electives

Primary majors choose **three** additional electives (27 or more units). Additional majors choose **four** additional electives (36 or more units). *Primary majors: see thesis requirement below.*

These Electives can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which is approved by the Academic Program Manager as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The Academic Program Manager will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

| | | |
|------------------|---|---|
| Philosophy | | |
| 80-380 | Philosophy of Language | 9 |
| 80-484 | Language and Thought | 9 |
| English | | |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-325 | Intertextuality | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-386 | Language & Culture | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| Modern Languages | | |
| 82-239 | Crazy Linguistically Rich Asian Languages | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |
| 82-305 | French in its Social Contexts | 9 |
| 82-334 | Structure of Chinese | 9 |
| 82-585 | Topics in Second Language Acquisition | 9 |
| 82-373 | Structure of the Japanese Language | 9 |

| | | |
|--------|--|---|
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |

Psychology

| | | |
|--------|-----------------------------|---|
| 85-354 | Infant Language Development | 9 |
| 85-421 | Language and Thought | 9 |

Language Technologies Institute

| | | |
|--------|--|----|
| 11-411 | Natural Language Processing | 12 |
| 11-423 | ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang. | 12 |
| 11-492 | Speech Processing | 12 |
| 11-422 | Grammar Formalisims | 12 |

Note: all 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor and with the Linguistics Academic Program Manager before registering.

Statistics and Data Science

| | | |
|--------|-------------------------------|---|
| 36-468 | Special Topics: Text Analysis | 9 |
|--------|-------------------------------|---|

SENIOR THESIS [PRIMARY MAJORS ONLY]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) 80-595 Senior Thesis. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the Academic Program Manager of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the semester preceding that in which the thesis research will be conducted..

Additional Major in Linguistics

The Linguistics additional major requires a total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. Additional majors are not required to write a thesis but must take four electives (36 or more units). All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor. If you are interested in obtaining an additional major in Linguistics, please reach out to the Academic Program Manager, Philosophy Department.

The Major in Logic and Computation

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The Bachelor of Science in Logic and Computation curriculum takes advantage of the preparation provided by the Dietrich College General Education Program in mathematics, philosophy, psychology, and statistics. It is flexible in that it permits students to focus on any of a number of areas including (but not limited to):

- computer science,
- artificial intelligence and cognitive science,
- logic and the foundations of mathematics,
- methodology and philosophy of science.

Curriculum

The course requirements for the major consist of seven core courses (including the Senior Thesis) and four electives. The core courses provide comprehensive background in logic, computability, and analytic philosophy.

Students in their first year and sophomore year, are expected to take three courses that provide preparation in computer science, mathematics, and statistics. Four advanced electives are chosen in the area of focus, as described below in the sample curricula, and should support independent research towards fulfilling the senior thesis requirement. In their senior year, **Primary and Additional Majors** in Logic and Computation will engage in original research under the supervision of a faculty advisor in 80-595 Senior Thesis (a workload equivalent of 12 units). Students are responsible for identifying a thesis topic and securing a faculty advisor prior to the start of the semester in which they plan to complete the thesis. Note: Students should work with the Academic Program Manager during their junior year to

begin the process of identifying their topic and potential advisors. However, with suitable planning and advice from the Academic Program Manager, it is possible to complete the program in two years, beginning in the junior year.

All courses, if taken at Carnegie Mellon University, must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major with another major or minor.

| | | |
|---------------|--|----------|
| Prerequisites | | 42 units |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 36-200 | Reasoning with Data | 9 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 21-127 | Concepts of Mathematics | 12 |

| | | |
|----------------------------|---|----------|
| Logic and Computation Core | | 63 units |
| 80-150 | Nature of Reason *Students should complete before their junior year. | 9 |
| 80-310 | Formal Logic *Students should complete before their junior year. | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |
| 15-122 | Principles of Imperative Computation *Students should complete this prerequisite before their junior year. | 12 |
| 15-150 | Principles of Functional Programming *Students should complete this prerequisite before their junior year. | 12 |
| 80-595 | Senior Thesis | 12 |

Logic and Computation Electives 36 units

Bearing in mind prerequisites, Logic and Computation majors must complete four advanced courses in areas that use logical and computational tools, such as philosophy, computer science, linguistics, mathematical logic, psychology, or statistics. The sequence of courses, mostly at the *300-level and above, must be selected in consultation with the Academic Program Manager.

Sample Curricula

Below are four samples of Logic and Computation curricula (beyond the core courses), each reflecting a different emphasis: Computer Science, Language and Information Technology, Artificial Intelligence and Cognitive Science, Logic and the Foundations of Mathematics, and Methodology.

Sample 1.

A student interested in **Computer Science** might take the following courses:

| | | |
|--------|--------------------------------------|----|
| 80-315 | Modal Logic | 9 |
| 80-413 | Category Theory | 9 |
| 15-312 | Foundations of Programming Languages | 12 |
| 15-317 | Constructive Logic | 9 |

Sample 2.

A student interested in **Artificial Intelligence and Cognitive Science** might take the following courses:

| | | |
|--------|---|---|
| 80-249 | AI, Society, and Humanity | 9 |
| 80-315 | Modal Logic | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |
| 80-411 | Proof Theory | 9 |
| 85-412 | Cognitive Modeling | 9 |

Note: If you are a Cognitive Science (<https://www.cmu.edu/dietrich/psychology/undergraduate/prospective-students/academics/cognitive-science/>) major (Department of Psychology) this additional major would complement your coursework.

Sample 3.

A student interested in **Logic and the Foundations of Mathematics** might consider the following courses:

| | | |
|--------|--------------------------|---|
| 80-254 | Analytic Philosophy | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |

Sample 4.

A student interested in **Methodology** might consider the following courses:

| | | |
|--------|--|---|
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 80-305 | Game Theory | 9 |

Additional major in Logic and Computation

The Logic and Computation major is also suitable as an additional major for students in Dietrich College or for students in other colleges within the University. Non-Dietrich students interested in an additional major in Logic and Computation need to take only those courses in the Dietrich College General Education Program that are prerequisites to courses required in the major; all other Dietrich College General Education requirements are waived for these students. Depending on the student's background, the requirements of the additional major in Logic and Computation can be fulfilled with as few as five additional courses. The Philosophy Department does not limit the number of courses that can be counted for other majors and minors around the university. In their senior year, the additional major in Logic and Computation will write a thesis under the supervision of a faculty advisor.

The M.S. Program in Logic, Computation and methodology

The Department of Philosophy also offers a graduate M.S. degree in Logic and Computation and Methodology, which culminates with the writing of a master's thesis. It is ordinarily a two-year program, but students in the Logic and Computation major are able to complete the additional requirements in one year. Interested students in the 5th-year Master's program (<https://www.cmu.edu/dietrich/philosophy/graduate/5th-year-masters.html>) Master of Science in Logic, Computation & Methodology, should contact the Academic Program Manager for more information on how to apply.

The Major in Philosophy

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The Major in Philosophy is intended to be flexible and to facilitate additional majors in other fields (including majors with a strong professional focus). It provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Pre-Law, Metaphysics and Epistemology, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the Academic Program Manager. The Major in Philosophy is a B.A. degree.

Curriculum

In addition to the general education requirements for the student's college, Philosophy primary majors and additional majors must complete 80-100 Introduction to Philosophy and nine Philosophy courses in the Areas listed below. The 80-100 Introduction to Philosophy requirement must be fulfilled before the first semester of the junior year. Only two of the remaining nine courses may be at the 100-level, and two of the nine courses must be at the 300-level or higher. All ten courses, if taken at CMU, must be taken for a letter grade and passed with a grade of "C" or above. Students are to choose one course out of each of the Areas 1-4, two courses out of Area 5, and may freely select three courses in Area 6. Students may double count any course for the major with another major or minor. As per the requirement of Dietrich College, a student's Grand Challenge First-Year Seminar course may not count toward the fulfillment of the major requirements.

| | | |
|----------------------------|----------------------------|---------|
| Introduction to Philosophy | | 9 units |
| 80-100 | Introduction to Philosophy | 9 |

| | | |
|-------------------------------------|--|---------|
| Area 1: Values and Normative Theory | | 9 units |
|-------------------------------------|--|---------|

One of the following:

| | | |
|--------|--|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |

| | | |
|--------|---|---|
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

Area 2: Philosophy of Mind/Language/Metaphysics 9 units

One of the following:

| | | |
|--------|---|---|
| 80-180 | Nature of Language | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-285 | Natural Language Syntax | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-383 | Language in Use | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-484 | Language and Thought | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |
| 80-580 | Seminar on the Philosophy of Language | 9 |

Area 3: Logic/Philosophy of Mathematics 9 units

One of the following:

| | | |
|--------|-----------------------------------|---|
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-212 | Arguments and Logical Analysis | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-315 | Modal Logic | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |
| 80-419 | Interactive Theorem Proving | 9 |
| 80-514 | Categorical Logic | 9 |
| 80-518 | Seminar on Topics in Logic | 9 |

Area 4: Epistemology/Methodology 9 units

One of the following:

| | | |
|--------|---|---|
| 80-150 | Nature of Reason | 9 |
| 80-201 | Knowledge and Justified Belief | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-305 | Game Theory ^{After Spring 2023} | 9 |
| 80-306 | Decision Theory | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |
| 80-326 | Epistemology of Machine Learning | 9 |
| 80-405 | Game Theory ^{Prior to Fall 2023} | 9 |
| 80-516 | Causality and Machine Learning | 9 |

| | | |
|--------|---|---|
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | 9 |
|--------|---|---|

Area 5: History of Philosophy 18 units

Two of the following:

| | | |
|--------|--|---|
| 80-150 | Nature of Reason | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-252 | Kant | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-551 | Seminar on History of Philosophy: Smith and Hume | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-350 | Adam Smith | 9 |
| 80-358 | Hume | 9 |
| 80-365 | Ramsey | 9 |

Area 6: Elective 27 units

Three other philosophy courses, or appropriate courses from other departments, with the permission of the Academic Program Manager.

Sample Curricula

Here are four sample curricula, reflecting different emphases.

1. For an emphasis on Law & Social Policy, a student might take:

| | | |
|--------|---|---|
| Area 1 | | |
| 80-335 | Social and Political Philosophy | 9 |
| Area 2 | | |
| 80-180 | Nature of Language | 9 |
| Area 3 | | |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| Area 4 | | |
| 80-208 | Critical Thinking | 9 |
| Area 5 | | |
| 80-150 | Nature of Reason | 9 |
| 80-250 | Ancient Philosophy | 9 |
| Area 6 | | |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

2. For an emphasis on Philosophy of Science, a student might take:

| | | |
|-----------|--|---|
| Area 1 | | |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| Area 2 | | |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| Area 3 | | |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| Area 4 | | |
| 80-220 | Philosophy of Science | 9 |
| or 80-221 | Philosophy of Social Science | |
| Area 5 | | |
| 80-250 | Ancient Philosophy | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| Area 6 | | |
| 80-150 | Nature of Reason | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-524 | Topics in Formal Epistemology: Topological Philosophy of Science | 9 |

3. For an emphasis on Ethics and Social Philosophy, a student might take:

| | | |
|--------|------------------------|---|
| Area 1 | | |
| 80-130 | Introduction to Ethics | 9 |
| Area 2 | | |
| 80-276 | Philosophy of Religion | 9 |

| | | |
|--------|---|---|
| Area 3 | | |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| Area 4 | | |
| 80-221 | Philosophy of Social Science | 9 |
| Area 5 | | |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| Area 6 | | |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |

4. For an emphasis on Philosophy of Mind, a student might take:

| | | |
|--------|---|---|
| Area 1 | | |
| 80-130 | Introduction to Ethics | 9 |
| Area 2 | | |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| Area 3 | | |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| Area 4 | | |
| 80-201 | Knowledge and Justified Belief | 9 |
| Area 5 | | |
| 80-251 | Modern Philosophy | 9 |
| 80-252 | Kant | 9 |
| Area 6 | | |
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |

Additional Major

Students who wish to pursue an additional major in Philosophy must fulfill the same departmental requirements as primary majors in Philosophy. Students can double count any course for the major with another major or minor.

The M.A. Program in Philosophy

The M.A. Program in Philosophy provides exciting opportunities to pursue post-graduate studies in Philosophy for students with a degree in Philosophy who wish to continue their work in a more focused and advanced way. Two areas of specialization are offered in line with the distinctive strengths of the Philosophy Department that are not reflected in its other graduate degree programs, namely **Ethics, Social and Political Philosophy, and Philosophy of Science**. The latter specialization offers emphases in **Mathematics, Psychology, Physics, and the Social Sciences**.

The course of study for the 5 (<https://www.cmu.edu/dietrich/philosophy/graduate/5th-year-masters.html>)⁵¹ year M.A. in Philosophy is very flexible, and can be tailored to a student's interests and background. For more information, please contact the Academic Program Manager.

Philosophy Department Minors

The Philosophy Department offers six minors, and the requirements are designed to be flexible and to allow students to tailor courses to their special interests, while providing some breadth.

- Ethics
- Linguistics
- Logic & Computation
- Philosophy
- Rationality, Uncertainty, and Choice: Formal Methods (RUC)
- Societal & Human Impacts of Future Technologies (SHIFT)

The Minor in Ethics

The Minor in Ethics introduces students to central ethical concepts and theories proposed and defended by the great philosophers of the past; it provides an understanding of how these theories and concepts can be applied to practical problems. This background in ethical theory and its applications should help students to respond more sensitively

and appropriately to the new and unavoidable ethical problems that technologies, businesses, unions, and branches of government must face.

Ethics minors must complete five philosophy courses in the areas listed below. All five required courses must be taken for a letter grade and passed with a grade of a "C" or above, except 80-500 Undergraduate Internship, which may be taken pass/fail.

Ethics Core Courses 27 units

Complete three courses from any of the following areas with at least two courses at the 200-level or higher.

| | Units | |
|--------|---|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

Ethics Electives 18 units

Complete two courses at the 200-level or higher. These courses may be additional courses from Ethics Core list above.

| | Units | |
|--------|---|---|
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

The Minor in Linguistics

Linguistics is the scientific study of human language. The central goal of the Linguistics Program is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Minor is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning. The Core courses cover the principal domains of linguistic analysis: phonetics and phonology, syntax, and meaning. Students then move on to the Extended Core, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core (27 units)

| Required | Units | |
|---------------------------------------|---------------------------|---|
| 80-180 | Nature of Language | 9 |
| Select 2 from the following 3 options | | |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-280 | Linguistic Analysis | 9 |
| or 80-285 | Natural Language Syntax | |
| 80-381 | Meaning in Language | 9 |
| or 80-383 | Language in Use | |

Extended Core: Choose 3 courses (27 units) from the Extended Core and/or additional courses from Core.

| Extended Core | Units | |
|---------------|---------------------------|---|
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |

| | | |
|--------|---|---|
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |

The Minor in Logic and Computation

The Minor in Logic and Computation provides students with general course work in logic, the theory of computation, and philosophy. Students must complete six courses, among them the following three core courses. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Logic and Computation Core Courses 27 units

| | Units | |
|-----------|-----------------------------------|---|
| 80-150 | Nature of Reason | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| or 80-210 | Logic and Proofs | |
| 80-310 | Formal Logic | 9 |
| or 80-311 | Undecidability and Incompleteness | |

Logic and Computation Electives 27 units

Students must take two courses in the Philosophy Department at the 300-level or higher, in subjects related to logic and computation. And an additional course at the 300-level or higher in an area that uses logical and computational tools, such as philosophy, computer science, linguistics, mathematics, psychology, or statistics. The choice of electives must be approved by the Academic Program Manager.

The Minor in Philosophy

The Minor in Philosophy requires five courses and gives students a broad philosophical foundation, requiring one course in Logic/Methodology, two courses in the History of Philosophy and two Philosophy electives. The minor complements any primary major from around the University. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Logic/Methodology Requirements 9 units

| Complete one course: | Units | |
|----------------------|---|---|
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-315 | Modal Logic | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |
| 80-365 | Ramsey | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |
| 80-514 | Categorical Logic | 9 |
| 80-516 | Causality and Machine Learning | 9 |
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | 9 |

History of Philosophy Requirements 18 units

| Complete two courses: | Units | |
|-----------------------|--------------------------------------|---|
| 80-150 | Nature of Reason | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-250 | Ancient Philosophy | 9 |

| | | |
|--------|--|---|
| 80-251 | Modern Philosophy | 9 |
| 80-252 | Kant | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-358 | Hume | 9 |
| 80-551 | Seminar on History of Philosophy: Smith and Hume | 9 |
| 80-365 | Ramsey | 9 |

Philosophy Electives 18 units

Students must complete 18 units in the Philosophy department at the 200-level or higher. The choice of electives must be approved by the Academic Program Manager.

The Minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC)

Students pursuing the minor in Rationality, Uncertainty, and Choice: Formal Methods (RUC) will learn interdisciplinary philosophical and mathematical approaches to reasoning about uncertainty and decision making in both individual and group contexts.

The RUC minor consists of three core requirements in **Game Theory**, **Decision Theory**, and a choice between the **Decision Analysis** and **Decision Models and Games** from the Department of Social and Decision Sciences. Students will then take 3 elective courses from two elective categories. Electives are intended to show how key concepts from the RUC core can be applied across many disciplines. The RUC minor uniquely complements majors from across Carnegie Mellon University and extends to fields such as economics and computer science. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core Requirements

| Complete all of the following: | Units | |
|--------------------------------|---------------------------|----|
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-223 | Decision Analysis | 12 |
| or 88-312 | Decision Models and Games | |

Note: Students must complete three elective courses from the following two categories and must complete at least one course in each category.

Elective Category 1: Formal Foundations 9-18 units

| | | |
|--------|--|----|
| 80-201 | Knowledge and Justified Belief | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-210 | Logic and Proofs | 9 |
| 80-315 | Modal Logic | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |
| 80-516 | Causality and Machine Learning | 9 |
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | 9 |
| 80-524 | Topics in Formal Epistemology: Topological Philosophy of Science | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-312 | Decision Models and Games | 9 |
| 88-379 | Data-Driven Decision Analysis | 9 |

Elective Category 2: Theory and Applications 9-18 units

| | | |
|--------|-----------------------------------|---|
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-252 | Kant | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |

| | | |
|--------|---------------------------------|---|
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |

The Minor in Societal & Human Impacts of Future Technologies (SHIFT)

Students pursuing the SHIFT minor will gain the skills, knowledge, and experience to successfully take on roles in integrated, multidisciplinary analyses of current and near-future computational technologies. The SHIFT minor requires eight total courses, with no limit to double-counting with other majors or minors. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

| | | |
|--|---------------------------|-------|
| Core Courses (2 courses, 10 to 18 units total) | | Units |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-445 | Shift Capstone Experience | 1-9 |

Area Courses (6 courses, 54 units total)

Note: Five of the six Area Courses must be taken in different departments

Technology area (18 units)

Courses that build basic technological competence, and teach concepts and frameworks that provide high-level understanding of computational technologies, including their possibilities and limits.

| | | |
|----------------------|---|-------|
| Complete two courses | | Units |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-320 | Social Web | 12 |
| 05-452 | Service Design | 12 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 16-467 | Human Robot Interaction | 12 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | 9 |
| 17-313 | Foundations of Software Engineering | 12 |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-355 | Program Analysis | 12 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 67-250 | The Information Systems Milieux | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Social & Behavioral Sciences area (18 units)

Courses that teach the concepts and frameworks of social and behavioral sciences (e.g., economics, psychology, sociology), including methods and analyses such as experimental design and quantitative and qualitative data analysis.

| | | |
|----------------------|---|-------|
| Complete two courses | | Units |
| 05-413 | Human Factors | 9 |
| 17-224 | Influence, Persuasion, and Manipulation Online | 9 |
| 36-200 | Reasoning with Data | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-321 | Negotiation and Conflict Resolution | 9 |
| 70-341 | Team Dynamics and Leadership | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-267 | Data Science for Political Science | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-435 | Decision Science and Policy | 9 |

Ethics, Policy & Design Area (18 units)

Courses that teach core concepts and frameworks to address and analyze ethical, policy, and design challenges relevant to current and near-future computational technologies.

| | | |
|----------------------|---------------------------------------|-------|
| Complete two courses | | Units |
| 05-413 | Human Factors | 9 |
| 08-200 | Ethics and Policy Issues in Computing | 9 |

| | | |
|--------|---|-----|
| 16-161 | ROB Freshman Seminar: Artificial Intelligence and Humanity | 9 |
| 17-224 | Influence, Persuasion, and Manipulation Online | 9 |
| 36-200 | Reasoning with Data | 9 |
| 51-173 | Design Center: Human Experience in Design | 9 |
| 51-241 | How People Work | 9 |
| 51-371 | Futures I | 4.5 |
| 51-373 | Futures II | 4.5 |
| 51-382 | Design Center: Design for Social Innovation | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-321 | Negotiation and Conflict Resolution | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 70-341 | Team Dynamics and Leadership | 9 |
| 70-364 | Business Law | 6 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-234 | Technology and Society | 9 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-130 | Introduction to Ethics | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-267 | Data Science for Political Science | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-405 | The Future of Warfare | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-435 | Decision Science and Policy | 9 |

Faculty

JEREMY AVIGAD, Professor of Philosophy - Ph.D., University of California, Berkeley; Carnegie Mellon, 1996-

STEVEN AWODEY, Professor of Philosophy - Ph.D., University of Chicago; Carnegie Mellon, 1997-

ADAM BJORNDAHL, Associate Professor of Philosophy - Ph.D., Cornell University; Carnegie Mellon, 2014-

CHRISTINA BJORNDAHL, Assistant Teaching Professor - Ph.D., Cornell University; Carnegie Mellon, 2014-

SIMON CULLEN, Assistant Teaching Professor of Philosophy - Ph.D., Princeton University; Carnegie Mellon, 2018-

KEVIN T. KELLY, Professor of Philosophy - Ph.D., University of Pittsburgh; Carnegie Mellon, 1985-

ALEX JOHN LONDON, K&L Gates Professor of Ethics and Computational Technologies - Ph.D., University of Virginia; Carnegie Mellon, 2000-

KRZYSZTOF MIERZEWSKI, Assistant Professor - Ph.D., Stanford University; Carnegie Mellon, 2020-

JOSEPH RAMSEY, Special Faculty and Director of Research Computing - Ph.D., University of California, San Diego; Carnegie Mellon, 2006-

RICHARD SCHEINES, Professor of Philosophy, The Bess Family Dean's Chair of the Dietrich College of Humanities and Social Sciences – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

TEDDY I. SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

WILFRIED SIEG, Patrick Suppes Professor of Philosophy – Ph.D., Stanford University; Carnegie Mellon, 1985–

MANDY SIMONS, Professor of Philosophy – Ph.D., Cornell University; Carnegie Mellon, 1998–

JOEL SMITH, Distinguished Career Teaching Professor of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 2000–

PETER L. SPIRITES, Professor of Philosophy, Marianna Brown Dietrich Professor and Head of Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1987–

DANIELLE WENNER, Associate Professor of Philosophy – Ph.D., Rice University; Carnegie Mellon, 2013–

THOMAS WERNER, Associate Teaching Professor of Philosophy – Ph.D., Rutgers University; Carnegie Mellon, 2003–

WAYNE WU, Associate Professor, Philosophy and the Neuroscience Institute – Ph.D., University of California, Berkeley; Carnegie Mellon, 2010–

FRANCESCA ZAFFORA BLANDO, Assistant Professor of Philosophy – Ph.D., Stanford University; Carnegie Mellon, 2020–

KUN ZHANG, Associate Professor of Philosophy – Ph.D., The Chinese University of Hong Kong; Carnegie Mellon, 2015–

KEVIN ZOLLMAN, Professor of Philosophy – Ph.D., University of California, Irvine; Carnegie Mellon, 2009–

Courtesy

FRANK PFENNING, Professor, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2002–

VINCENT CONITZER, Professor of Computer Science, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022–

Special Faculty

JONAS FREY, Special Faculty – Ph.D., Paris 7 University (now Université Paris Cité); Carnegie Mellon, 2016–

DERRICK GRAY, Special Faculty – Senior Lecturer – Ph.D., Rice University; Carnegie Mellon, 2013–

Emeriti Faculty

ROBERT CAVALIER, Teaching Professor (Emeritus) – Ph.D., Duquesne University; Carnegie Mellon, 1987–

CLARK GLYMOUR, Alumni University Professor of Philosophy (Emeritus) – Ph.D., Indiana University; Carnegie Mellon, 1984–

DANA S. SCOTT, Hillman University Professor of Mathematical Logic, Computer Science and Philosophy (Emeritus) – Ph.D., Princeton University; Carnegie Mellon, 1981–

Department of Philosophy Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

80-100 Introduction to Philosophy

All Semesters: 9 units

Even philosophers have a hard time explaining what exactly philosophy is. Instead of attempting a definition, one might instead list some of the questions philosophers try to answer. Like most other academic fields, philosophy has its own sub-disciplines, and each of these has its own questions it tries to answer. In this course, we will be looking at questions from several of these areas of philosophy, including: What is the mind? Do we have free will? What does the answer to that question mean for practices of reward and punishment? Is morality relative? What, if anything, is its connection to religion? How can I know the right thing to do? How can I know anything? This class isn't a historical introduction to philosophy, and we will be jumping around through history and subjects as we please, concerned only with interesting questions and good answers. As a whole, the course will strongly emphasize some of the basic skills of doing just about any kind of philosophy: how to recognize and understand arguments, how to evaluate them, and how to construct your own. As it turns out, these are skills you need to successfully navigate your way through just about any field of study and any career. This course will include a fair amount of writing, but you'll be getting lots of help from me, from your TA, and even from your peers.

80-101 Dangerous Ideas in Science and Society

Fall and Spring: 9 units

Do cancel culture and "wokeness" stifle free speech on campus? When should campus speakers be protested or disinvited? Should race be considered in college admissions? Should we use genetic engineering to create super-intelligent babies? Under what circumstances, if any, is abortion permissible? When, if ever, can a doctor kill a newborn baby or a dying patient? If we can in the future, should we end human aging, allowing people to live for thousands of years? Does civilian gun ownership make people safer, and if not, should it be allowed anyway? Is the case for defunding the police compelling? Should the United States open its borders to more immigrants? Has neuroscience shown that free will is an illusion? Could a digital computer become sentient? What is the probability that we are living in a computer simulation? Is it rational to believe in God in a world that contains so much suffering? These are some of the toughest, most pressing questions of current social, moral, and philosophical inquiry. Philosophers address them by producing intricate and often beautiful arguments. In this course, you will assess those arguments and produce your own. You will learn how to have challenging, productive, and respectful discussions across political and moral differences. You will learn to think like a philosopher - to strip an argument presented in prose to its essentials and plainly expose its structure. This course will improve the clarity and rigor of your own thinking and writing. It will put you in a position to make progress on hard questions like those mentioned above. And it will improve your ability to crisply convey your ideas - an ability that will serve you well not just in class, but also in daily life.

Course Website: <https://youtu.be/XVeKvzVuO4> (<https://youtu.be/XVeKvzVuO4/>)

80-130 Introduction to Ethics

Fall: 9 units

Philosophical ethics, or moral philosophy, covers a lot of ground. It asks and tries to answer questions like: What's good in life? What matters? What should I (and others) do? How should I (and others) act? What kinds of things out there must be treated ethically? Do we have moral duties to (at least some) non-human animals? Is morality subjective? Are there actually any objective moral truths? Morally speaking, what (if anything) is the difference between killing someone, and simply letting them die? In trying to answer these questions (and others), we'll engage in some wonderfully weird thought experiments, class discussions, smaller group discussions, debates, etc. We'll study and critique several moral theories which try to explain and help guide our moral judgments, and we'll try to apply these theories to real-life moral controversies. Past classes covered topics including drug prohibition, abortion, euthanasia, and physician-assisted suicide. This is an introductory philosophy class, so you'll be learning how to read, critique, do, and write philosophy generally, not just ethics. Considerable time and effort, both in lectures and in recitations, will be spent helping you learn to recognize and evaluate philosophical arguments, as well as empowering you to create, improve, and defend your own arguments in class assignments.

80-135 Introduction to Political Philosophy

Spring: 9 units

At the heart of political philosophy lie fundamental questions such as: What constitutes a just society? How, and under what circumstances do individuals incur political obligations to a particular state? This course provides a systematic investigation of the way such questions are answered by dominant schools of liberal political theory, such as the social contract tradition, utilitarianism and libertarianism. Later we will introduce critiques from socialist, and feminist theorists. Readings are drawn from classic works by authors such as Plato, Hobbes and Locke, and from the works of more contemporary theorists like Rawls, and Nozick.

80-136 Social Structure, Public Policy & Ethics

Intermittent: 9 units

The course will consider ethical questions surrounding social structure and public policy. It will analyze the role of political institutions and individual citizens in dealing with some of the greatest challenges facing our world: Global health crises, the spread of (and threats to) democracy worldwide, and world poverty. Some of the questions we will consider include: Are developed countries obligated to ameliorate poverty by providing foreign aid? What is democratic governance, and what do democratic representatives owe to their constituents? Should wealthy nations and corporations assist in the fight against life-threatening diseases worldwide? The course uses ethical and political theory, case studies, and empirical evidence to consider these questions.

80-150 Nature of Reason

Spring: 9 units

This course provides an accessible introduction to the historical development of philosophical ideas about the nature of reasoning and rationality (with a focus on mathematics and the sciences), from ancient to modern times. The first part of the course traces the search for deductive methods for obtaining certain knowledge, starting with Aristotle and Euclid all the way to the work of Boole and Frege in the 19th century. The second part of the course considers the history of skepticism about empirical knowledge, covering Plato, Descartes, Pascal, and Hume, along with replies to skepticism in the works of Bayes and Kant. The third part of the course discusses theories of the nature of the mind and mental processes, culminating in the computational conception of the mind that underlies contemporary cognitive science.

80-180 Nature of Language

Fall and Spring: 9 units

Language is used to talk about the world or to describe it, but how do we go about describing language itself? Linguistics is the name given to the science of language, whose task it is to give such a description. The discipline of linguistics has developed novel tools for describing and analyzing language over the last two hundred years and in this course we learn what these tools are and practice applying them. Sub-areas of linguistics which we study include phonetics (the study of speech sounds), phonology (the study of sound systems), morphology (the study of parts of words), and syntax (the study of combinations of words). Furthermore, we highlight various respects in which language and linguistics intersects with societal issues. The methods of linguistics are useful in the study of particular languages and in the study of language generally, so this course is useful for students of foreign languages as well as those interested in going on to study language acquisition, psycholinguistics, sociolinguistics, philosophy of language, and computer modeling of language.

80-184 Disagreeable Language: talk in the age of polarization

Intermittent: 9 units

What do you do when confronted with opinions that (to you) are obviously wrong - supported by facts that are not even based in (your) reality? This is a situation we more and more find ourselves facing, or would if we ever ventured out of our own ideological bubble (which is constantly replenished by Big Tech and only with information pre-matched to our biases). It is held in place by human language itself - our supposed primary means of communication. While it is true that pictures can lie and #8212; one hundred years ago Arthur Conan Doyle got taken in by the Cottingley pixie photographs, and now there's CGI and Deepfake and #8212; language has always been the premier instrument for the conveyance of untruths. And when the facts themselves are up for grabs, the traditional approach and #8212; going outside of language for confirmation and fact-checking - doesn't work either. Can anything be done about this precarious situation? Disagreeable Language explores a possible solution and #8212; through linguistics, the study of human language. A sub-field of linguistics is the study of language structure, an enterprise which is self-contained and relies on no information outside of language and speaker intuitions. But this independence from reality may make linguistics the right tool for the detection of reality. If patterns of untruth leave their mark in language itself, linguistic techniques would be the way to reveal them. That could provide an escape route out of the matrix. At the very least, students in this course will learn basic methods for interrogating the language we use to get through to one another, that is, basic methods for doing linguistics.

80-201 Knowledge and Justified Belief

Intermittent: 9 units

Knowledge acquisition is central to the university's mission. The sciences seek knowledge of nature. Statistics concerns methods for finding and establishing scientific knowledge. Machine learning concerns the automated generation of knowledge. Database theory concerns the maintenance of knowledge. But then what are knowledge, justified belief, truth, and evidence, and how do all of those concepts fit together? The branch of philosophy that studies those questions is called epistemology, which just means "study of knowledge". This class confronts the central epistemological questions. Topics include the analysis of knowledge and justification (what are they?), skepticism (the justifiability of beliefs that goes beyond the data available), and the relationship between knowledge and deductive logic (are the consequences of knowledge knowable?). The proposed answers involve a subtle interplay of logic, probability, causation, and counterfactual reasoning. The course is self-contained, so there are no prerequisites.

80-208 Critical Thinking

Intermittent: 9 units

This course is an introduction to practical reasoning. The course will contain an elementary introduction to concepts important for reasoning and decision making, such as validity, probability, and utilities. Students will extensively practice critically analyzing and evaluating a wide variety of arguments found in newspapers, magazines, and elementary accounts of scientific reasoning. In order to help students develop the skills to analyze and evaluate arguments, the course will introduce several software packages recently developed at CMU that help students diagram arguments and causal reasoning; these packages have been shown to improve students critical reasoning skills. In addition, students will learn about a wide variety of statistical, logical, psychological, and causal fallacies that are used to mislead people.

80-210 Logic and Proofs

All Semesters: 9 units

Logic and Proofs is a web-based course and introduces students to central issues in modern logic. It is designed for individual learning with rich interactive environments and dynamic intelligent tutoring. The material is presented on-line, and most exercises are done on-line as well. Readings of historical and philosophical character complement the core content. This on-line course is supplemented, indeed given additional grounding, by weekly meetings in very small groups. There, we have collaborative reviews, substantive discussions and critical reflections. The central question of the course is this: How can we analyze the structure of rational discourse or, more specifically, the logical structure of argumentation? An answer to this question requires: (i) uncovering the logical form of statements; (ii) defining the correctness of logical steps; (iii) formulating inference rules for the logical forms; (iv) designing strategies for argumentation with the inference rules. The course takes these steps for both sentential and quantificational logic.

Course Website: <https://oli.cmu.edu/courses/logic-proofs/>**80-211 Logic and Mathematical Inquiry**

Fall: 9 units

Since ancient times, mathematical arguments have served as a paradigm for rational inquiry. We will study fundamental mathematical concepts and informal proofs as they occur in everyday mathematics. We will also use the methods of mathematical logic, which provides formal symbolic languages, to help us understand the structure of a mathematical argument. Finally, we will make use of a new computational "proof assistant," called Lean, to develop fully rigorous, machine-checked proofs.

80-212 Arguments and Logical Analysis

Intermittent: 9 units

Are there rational methods that can further our knowledge? The notion of rational inquiry presupposes that there are appropriate methods for the pursuit of knowledge. In this course, we will investigate the means by which a successful argument justifies its conclusion, as well as various subtle ways in which other arguments fail. The course will explore the use of logic as an instrument in the study of arguments and reasoning, and it will serve as a gentle introduction to the elementary concepts of formal logic. We will take a historically informed approach to studying logic and argumentative fallacies, and we will discover that logical tools and methods are useful for constructing and analyzing arguments in all disciplines, from philosophy and history to psychology and physics. Our goals are to acquire a solid grasp of some fundamental tools of modern logic, and learn how to use them to make our thinking and writing clearer, more precise, and more critical. To this end, our coursework will consist in homework and exams on topics in logic, as well as writing assignments on a variety of topics. This course is intended for students from any discipline who would like to improve their writing and critical thinking skills, as well as students who are interested in learning logic without having had prior contact with the subject.

80-220 Philosophy of Science

Intermittent: 9 units

In this course, we will examine some historical case studies (e.g., the Copernican revolution in astronomy) against which we will assess views pertaining to the significance, justification, and production of scientific knowledge. For example, should scientific theories be understood literally or as computational devices for deriving new predictions? How can universal conclusions ever be justified by a finite data set? Does explanation contribute to a theory's confirmation by the evidence? Does science aim to find the truth? Is probability in the world or only in our minds? Is explanation a matter of finding causes or are causes whatever it is that explains? Is scientific rationality objective or culture-relative?

80-221 Philosophy of Social Science

Spring: 9 units

This course will explore numerous philosophical issues that arise in the practice of various social sciences. One central question of the course is whether we can use traditional scientific reasoning to understand social phenomena, e.g. social inequalities, violence, changes in politics, discriminatory practices, economic forecasting, etc. in the same way that we use them to understand natural phenomena, e.g. gases, organisms, protein structure, and planetary orbits. Some of the more specific questions we address are: Because humans possess free will and act with intentions while light rays and planets in motion do not, are we forced to use different kinds of explanations in the two cases? How can we explain social institutions that depend upon cooperation when there considerable psychological evidence that cooperation doesn't help us in achieving our own personal goals? Whereas natural scientists actively conduct experiments, social scientists can often only collect statistical and qualitative data. Does this difference prevent social scientists from inferring causal relations and laws of social behavior? Is our understanding of social phenomena always value laden given that values are an inherent aspect of social life?

80-226 The Nature of Scientific Revolutions

Fall: 9 units

Science is an ever-changing enterprise. Most scientific advances, though significant, occur within a stable framework of accepted theories and data. A few episodes of change in the history of science involve discarding and replacing fundamental theories of the world. These are often accompanied by significant changes in the vocabulary in which those theories are expressed, the tools used by scientists, the phenomena on which scientists focus, and the kinds of explanations they consider acceptable. A very small number of these episodes change the way humanity views its ability to know the natural world and its place in the universe. The latter two kinds of change in science have often been called "scientific revolutions." We will focus on three such radical transformations: The "Copernican Revolution" (or "the Scientific Revolution") of the 16th and 17th centuries, the Darwinian revolution of the 19th century, and the quantum revolution of the late 19th and 20th centuries. This course has two intertwined components: history of science and philosophy of science. In the historical component, we will examine in some detail the three major scientific revolutions. The philosophical components will help us understand the reasoning involved in scientific theory change. This course does not require detailed knowledge of any of the sciences used in examples of revolutionary change.

80-234 Race, Gender, and Justice

Intermittent: 9 units

Race and gender, along with their interfaces and interactions with such other social identities as sexuality, (dis)ability, and class, structure our experience of almost every aspect of our social and political reality. Philosophers approach these kinds of social identities from a variety of perspectives. They ask what these kinds of social categories really are, what they mean for the ways we live our lives and the ways we perceive and understand the world, how they have (mis)informed our theoretical and practical understanding of the nature of justice and political power, and what is owed to those affected by racial and gendered injustice. This course explores these topics, drawing on tools and perspectives from epistemology, ethics, and especially social and political philosophy.

80-244 Environmental Ethics

Fall: 9 units

In this class, we'll try to figure out what obligations we might have to the natural environment and the non-human living beings within it, as well as what justice requires of us in our use of natural resources given the needs of other human beings. Among other things, we'll spend considerable time on animal ethics: What moral obligations do we have to non-human animals? Is it morally OK to eat them? Does a dog count (morally speaking) as much as a human? Does a factory-farm chicken count as much as a wild endangered tiger? Then, given that many of the most pressing environmental problems like climate change are collective action problems, we'll consider why these problems are so sticky, what obligations we have as individuals in dealing with these problems, and what a just collective solution might look like. To that end, we'll examine the processes fueling climate change, we'll look at who is responsible for these processes, and we'll try to determine whether any current proposal to deal with climate change is an effective, just response to the problem.

80-245 Medical Ethics

Spring: 9 units

This course provides a detailed introduction to core ethical issues in medical ethics and public policy. Topics include: the moral responsibilities of health care providers to patients and various third parties such as the government or insurance companies, the status of health as a social good, questions of justice in access to health care, and questions of individual liberty and social responsibility at the ends of life including issues such as cloning, abortion, physician assisted suicide, and the definition of death. We will also examine specific ethical issues in the conduct of medical research and look at the impact of technological innovation on our notions of health, disease, life, death, and the family. While the course engages such substantive ethical issues it also attempts to sharpen students' skills in practical reasoning through argument analysis, analogical reasoning, and the application of theory and principles to particular cases.

80-246 Moral Psychology

Intermittent: 9 units

In this course you will read cutting-edge scientific work on morality and you will learn to interpret it in light of recent lessons from biology and computer science. This course will also introduce you to distinctions that philosophers have found useful for moral-psychological and meta-ethical theorizing. Topics that we may discuss include: the psychology of normative ethics; moral emotions (e.g., disgust, guilt, shame, pride, etc.); the origins of morality in human and nonhuman animals; moral development in babies and children; the role of moral judgment in folk theorizing; and mathematical models of morality inspired by insights from machine learning. However, this course is exploratory and designed to be open-ended. I hope and expect that students will help to determine what we read and discuss.

80-249 AI, Society, and Humanity

Fall: 9 units

AI and robotic technologies are developing rapidly and are increasingly incorporated into decisions, practices, and activities that impact individual and social interests. To ensure that these technologies advance meritorious goals without undermining important values or relationships, stakeholders must be able to understand the diverse ways in which new technologies can impact the lives of individuals and communities, the diverse dimensions on which such impacts can be evaluated and measured and where in the lifecycle of product development these various impacts might be anticipated and addressed. Through a series of case studies of current or near-future AI and robotics technologies students in this course will explore frameworks for assessing, evaluating and regulating novel technologies with the goal of ensuring that they support and advance human interests and social values.

80-250 Ancient Philosophy

Fall: 9 units

This course will cover Ancient Greek philosophy from the pre-Socratics to the later Hellenistic writers. We will prepare the background for Socrates and Plato by studying major Presocratic philosophers such as the Milesians, Heraclitus, and Parmenides, and then dive in to a careful study of some of the central works of Plato and Aristotle. A key theme of the class will be the way in which Socrates, Plato, and Aristotle sought to define philosophy in opposition to sophistry, and how the lessons learned from their confrontation with sophistry informed their ethical and metaphysical thought. The final sections will discuss post-Aristotelian movements such as Epicureanism, Skepticism, and Stoicism.

80-251 Modern Philosophy

Spring: 9 units

This class will focus on the history of Western philosophy in the modern period, with special emphasis on the "early modern" era of roughly 1600-1800. Massive upheavals and conflicts in science, politics, and religion fueled attempts to find new ways of making sense of the world, and we will try to situate our philosophers within this rapidly evolving intellectual context. In particular, we will examine the impact of these changes on two subfields of philosophy: metaphysics (the study of the nature of reality, distinguishing it from mere appearance), and epistemology (roughly, the study of knowledge itself). We will ask, and attempt answers for, questions like: What is knowledge, can we achieve it, and if so, to what extent? To what extent, if any, can our most basic scientific instruments, the human senses, lead us to the true nature of the world? These questions will unavoidably send us down paths into other subfields, like philosophies of mind, of free will, of ethics, and of religion. After reading early modern philosophers like Ren and #233; Descartes, Princess Elizabeth of Bohemia, John Locke, David Hume, and Immanuel Kant, we will turn to some more recent work in the modern and contemporary eras to see what lessons (if any) were learned, and what new approaches (if any) have been taken in the quest for knowledge and reality.

80-252 Kant

Intermittent: 9 units

Immanuel Kant was a CMU sort of person. He was an enthusiastic follower of Isaac Newton, and his approach to fundamental philosophy was: "what would robotics be like from the viewpoint of the robot?" From that starting point, he investigated what would have to be the case for the robot to know anything about its environment. The resulting "critical philosophy" defined the relevant philosophical vocabulary for generations of prominent mathematicians and scientists into the 20th century, and is pivotal background both for both the "analytic" and the "continental" schools of philosophy. This course starts with essential background reading in pre-Kantian, early modern sources, including Descartes. Then it focuses on a detailed reading of Kant's Critique of Pure Reason and related texts. Course requirements include written answers to reading questions and two short paper projects. There are no prerequisites.

80-253 Continental Philosophy

Intermittent: 9 units

This course provides students with an overview of key movements in European Philosophy. The historical background covers Descartes, Kant, Kierkegaard, and Nietzsche. The central tenets of phenomenology and existentialism (e.g., intentionality, Being-in-the-World, Bad Faith) will be discussed in the context of selected works from Husserl, Heidegger, Sartre and Merleau-Ponty. The course will conclude with the background for and current work of Habermas.

80-254 Analytic Philosophy

Intermittent: 9 units

This course examines the revolutionary impact of philosophy at the turn of the 20th century on contemporary thought and progress. By the 1920s some scientists and philosophers became hopeful that the end of the long tradition of philosophical deadlock was finally within reach. Buoyed in particular by Einstein's theory of relativity and the invention of modern logic, they created a new kind of philosophy with the goal of applying logical and empirical methods to philosophical problems. This new approach led to new puzzles and paradoxes, along with a focus on the age old question of what can be known and what is meaningful. The modern fields of linguistics, cognitive science, and information and computer sciences all owe a debt to these sources, as does of course contemporary philosophy. Our quest will be to understand both what authors like Frege, Russell, and the Vienna Circle were up to in the first place, and how their work contributed to the world we live in today.

80-255 Pragmatism: Making Ideas Work

Intermittent: 9 units

American Pragmatism represented an energetic attempt to bridge the divergent cultures of science and the humanities. The movement's founder, C.S. Peirce, was trained in chemistry and worked as a physicist, but he was also deeply concerned with the contemporary philosophical portrayal of science, which distinguished sharply between theoretical knowledge and practice. Peirce responded by constructing a comprehensive philosophy emphasizing the scientific importance of community, fallibility, and action. Pragmatism was developed and popularized by William James, who aspired to be a painter and ended up as an acknowledged founder of modern empirical psychology. James extended Peirce's position by defending the role of values in even the purest of empirical sciences. John Dewey, who is also well-known for his role in education, interpreted science as an evolving social system and developed a theory of aesthetics based on what we now call the psychology of problem solving. The pragmatists made lasting contributions to modern statistics, logic, and social science and their emphases on community, fallibility, action, and value in science are still of primary importance in philosophy and in the ongoing dialogue between the scientific and humanistic cultures.

80-256 Modern Moral Philosophy

Intermittent: 9 units

This course will follow moral theory through the modern era (roughly 1600-1900), with special emphasis on the works of Hobbes, Hume, and Kant, as well as the development of utilitarianism. Since moral theorizing was only one part of these thinkers' larger systems of philosophy, it cannot be fully separated from questions of metaphysics and epistemology (e.g. free will, determinism, materialism, etc.), and we'll spend some time situating their ethical thought within their larger projects. In doing so, we'll also examine these theories within the context of the rapidly changing social, political, and scientific landscape of the modern period.

80-257 Nietzsche

Intermittent: 9 units

During his life in the late 19th-century, Friedrich Nietzsche was a relatively obscure German philosopher. Since his death, however, he has become deeply influential and well-known, and was a source of inspiration for many important 20th-century thinkers. Despite this popularity, Nietzsche's philosophy remains relatively mysterious, and often misunderstood. Much of his writing consisted of aphorisms, rather than more traditional prose and arguments, and many of his positions seem to contradict one another. This course will cover a broad range of Nietzsche's writings, focusing on such central concepts as the will to power, eternal recurrence, and the oft-misunderstood Übermensch ("overman"). Throughout, we will focus on developing a consistent interpretation of an enigmatic philosopher whose views have been mischaracterized and misappropriated throughout the past century.

80-261 Experience, Reason, and Truth

Intermittent: 9 units

A central issue in Western philosophy has been whether reason or experience (or some of both?) provides the foundations for human knowledge. This course explores that question by looking at various "empiricist" vs. "rationalist" debates from the 17th century to the present day. We will focus on the problems encountered in trying to give an adequate account of the our knowledge of the external world, the structure of our minds, and the nature and limitations of human knowledge. The scope of our investigation will extend to the nature of mathematical knowledge, to "thought experiments" in both science and philosophy, and to "nativism" vs. "empiricism" issues in contemporary cognitive science and moral theory. The course has two main goals: (1) to study key metaphysical and epistemological issues surrounding the nature of human knowledge and (2) to help improve our analytical and critical skills by extracting and evaluating various relevant philosophical arguments.

80-270 Problems of Mind and Body: Meaning and Doing

Fall: 9 units

Central to our existence is meaning and our responses to it. We believe and desire things and on the basis of these attitudes, we make things happen. How can meaning exist in a seemingly mindless world? How can the world give rise to a mind capable of agency? This course tackles the mind/body problem in respect of explaining meaning and human action. We tackle philosophical problems with serious engagement with empirical work from psychology and neuroscience. Students taking the course will tackle these problems with emphasis on developing analytical abilities.

80-271 Mind and Body: The Objective and the Subjective

Fall: 9 units

This course is about the subjective and the objective. "Subjective" captures the distinctive features that characterize what it means to be a psychological subject. This includes the power to represent, to think, feel, sense and in general to be conscious. Subjective features seem radically different from the physical world of matter and forces, a world that seems meaningless, unthinking and nonconscious. How can the subjective be rooted in the objective? We address this central philosophical problem by engaging philosophy with science. In this course, we will investigate thinking, sensing, imagining, dreaming, hallucinating, mindfulness and self-knowledge. As a result, we will explore how the subjective might be the objective. Students will develop analytical techniques such as conceptual analysis and argument analysis.

80-275 Metaphysics

Intermittent: 9 units

The topical agenda of this course will vary. Typical topics include the problem of personal identity, the nature of human freedom, the nature of the self, the nature of reality and being, the nature of causality, and the question of whether solutions to such problems can be given. Classical as well as contemporary philosophic texts will be studied. For Spring 2011: Issues we will consider, in no particular order, include: Do properties exist? Why should you think there is an external world? What is a number? Why should you think other people have mental states? What are natural kinds? What constitutes the identity of things through time? What constitutes the identity of persons through time? What does determinism mean? Is there freedom of the will? What is possibility? What is necessity? Are there other possible worlds? When does one event cause another, and what does that mean? What could a deity be, and should you think there is one?

80-276 Philosophy of Religion

Intermittent: 9 units

Historically and cross-culturally, philosophy tends to emerge as an effort to understand religion. Whether or not one is a believer, religion can be viewed as a "stress test" of the concepts we bring to our understanding of the mundane world. Can we know that there is an infinite being behind mundane reality? What can we comprehend about such a being? Is morality prior to or subject to that being's will? Can such a being be innocent of our wrong-doing? If there is such a being, are we responsible for anything? All of those questions depend as much on what we mean by possibility, freedom and responsibility as they do on the truth of religion. In this class, we fearlessly confront those questions and, in the Carnegie Mellon spirit, we relate each philosophical reading to relevant issues in science and logic. Since the philosophy of religion literature focuses primarily on a Judeo-Christian context, the class begins with a short survey of the religious contexts of ancient Greece, Hinduism, and Buddhism to provide points of reference from which to question Judeo-Christian presuppositions.

80-280 Linguistic Analysis

Spring: 9 units

How do physical events (sounds) or physical objects (marks on paper) create or transmit meaning? Linguistic values are assigned to sounds and marks, based on specific physical features, creating phonemes and graphemes. Juxtapositions of phonemes and graphemes create morphemes, minimal units that hold meaning, with syntax arranging morphemes into sentences, minimal units of information. Further structural changes change the mood of a sentence and give it new function - as a request for information, demand for action, presentation of alternatives, and so on. The goal of this course is to investigate the structure of basic sentences and then the changes to structure by which communicative function is realized. Building on material taught in *Nature of Language*, this course looks in detail at the syntax of human languages, taking into account cross-linguistic variety.

Prerequisite: 80-180

80-282 Phonetics and Phonology I

Fall: 9 units

This course aims to provide students with practical tools for the study of speech sounds. The first step in this analysis is isolating the speech sounds themselves, for any particular language. Following this, the relation between the articulatory features of sounds and their acoustic properties is examined using spectrograms and other devices. Basic phonological notions are covered, tracing their development in the twentieth century up through optimality theory. In optimality theory, contrast and allophonic variation are explained in terms of an input-output device which selects the most harmonic candidate still faithful to phonemes in the input. The course should be relevant not only to linguistics students, but to students of language generally, with applications to sociolinguistics, child language development, speech recognition technologies, and the study of foreign languages.

Prerequisite: 80-180

80-283 It Matters How You Say It

Spring: 9 units

Why do languages give us multiple ways to say the same thing? Given that in English we can say "My dog ate my homework," why do we sometimes prefer "My homework got eaten by my dog"? Why do we sometimes choose to refer to someone with just a pronoun ("he"), and sometimes choose their full name ("Charles Dickens")? What's the difference between telling someone: "This expensive coffee is tasteless," or telling them: "This tasteless coffee was expensive"? This course is about the choices that languages give us for conveying a particular message, and the communicative effects of those choices. We will see that it is both the words you use and the way you put them together that determines the total communicative effect of your utterance. While the course will focus on English, students will have an opportunity to work on another language of interest in their final project.

80-284 Invented Languages

Fall: 9 units

Language is normally something that develops and changes organically within human communities, without much in the way of organized design or invention. Over the centuries, however, many have succumbed to what J. R. R. Tolkien called the "secret vice" of language creation. The purposes of these invented languages have been diverse. Some, like Tolkien's Elvish languages, Okrand's Klingon, and Peterson's Dothaki and Trigedasleng have been designed for artistic or entertainment purposes: they have set out to be "natural" languages within fictional worlds. Others, like Zamenhof's Esperanto, Brown's Loglan, and Elgin's L and #225;adan have tried to address perceived inadequacies of the natural languages that their creators saw in the world around them. The of study language invention is thus both the study of a distinctive art form, and an exploration of the history of how people have thought about language in different ages and societies. In this course, we will explore the linguistic considerations involved in language invention, and the linguistic lessons of the history of invented languages, with a particular emphasis on applying these insights to our own language invention projects. Over the course of the semester, students will be expected to develop invent their own languages, and to complete various shorter assignments to supplement relevant ideas and skills. This course does not assume any background in linguistics, and is intended to accommodate both newcomers and advanced students.

80-285 Natural Language Syntax

Spring: 9 units

This course regards modern linguistics as a set of powerful tools for understanding and using language, and among all the subfields of linguistics, syntax as one of the most powerful. There are, however, many approaches to syntax so how should one choose which syntax to study? In 1957, Chomsky published *Syntactic Structures*, building on earlier research but at the same time providing a novel approach to age-old problems in linguistics, particularly the productivity problem and the learning problem. (How do speakers produce and understand novel sentences, and how do children learn without being taught?) While it is true that the field has progressed far since 1957, *Syntactic Structures* still stands out for its simplicity and usefulness. In this course we look at how more recent developments in syntax can be reconciled with this earlier approach. Particular focus is on how students can use syntax, in learning other languages and in refining their own use of language.

Prerequisites: 80-284 or 80-180

80-286 Words and Word Formation: Introduction to Morphology

Fall: 9 units

How many words do you know? Is 'gonna' one word or two? How many meanings does 'unlockable' have? If someone can be 'inept', why can't they be 'ept'? In this course we study the linguistics of words and word formation, known as morphology. We begin by asking what a word is, about the internal structure of words, and how new words are formed. Throughout, we will consider these questions from a cross-linguistic perspective, looking at morphological data from a wide range of languages. We will also consider how morphology interacts with other subfields of linguistics, including phonology, syntax and semantics. Finally, we will survey morphological questions from the perspectives of language acquisition, psychology, and cognitive science.

Prerequisite: 80-180

80-287 Language Variation and Change

Spring: 9 units

We all know that languages differ and change, and that even two people who know the "same" language can sound quite different to each other, use different words, or even different sentence structures. This course takes students on a tour through linguistic difference across languages, within languages, and over time. We will look at how historical linguists reconstruct dead languages, how sociolinguists model language change, and how linguistic typologists assess whether some linguistic features (e.g., word order) are more or less common than others. We will also explore how linguistic variation and change are related to issues of social status and political power, and we'll investigate explanations for variation and change, drawing on literature from computational modelling and psycholinguistics. There is no prerequisite, and no prior linguistic knowledge is assumed.

80-288 Intonation: Transcription and Analysis

Spring: 9 units

Intonation is the melody of speech: how a speaker's pitch changes over the course of an utterance, along with the placement of emphasis, or sentence-level stress. Intonation and stress contribute to the interpretation of utterances in multiple ways. For example, the questions "Did BOB go to the store?" and "Did Bob go to the STORE?" contain the same words, but request different information. Similarly, whether the sentence "Bob went to the store" is interpreted as a statement or as a question, and whether as expressing certainty or uncertainty on the part of the speaker, depends on its intonation. Features of intonation can also convey information about the speaker's attitudes and affect: sarcasm and irony, for example, may be signaled by intonation. The goal of this course is two-fold. First, students will learn about the phonetic correlates of intonation and stress, and learn how to analyze intonation as a system of high and low tones, using the intonation transcription system ToBI. This will enable students to accurately describe the intonation pattern of an utterance. Second, students will learn how intonation is used to convey semantic and pragmatic information. The course will focus primarily on English, but other languages will be explored to serve as a basis of comparison. The course will be of interest to students interested in learning some of the intricacies of face-to-face linguistic communication. Students in the departments of English, Modern Languages, Language Technology, Human-Computer Interaction, and Psychology will find material relevant to their major topics. The course serves as an elective for the Linguistics Major, and is a natural companion to other courses on the expression of linguistic meaning: Meaning in Language, Language in Use, and Syntax and Discourse. The course requires basic background in phonetics.

Prerequisites: 80-488 or 85-385 or 80-180 or 80-284 or 85-356

80-305 Game Theory

Fall: 9 units

Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the Prisoner's Dilemma (pitting rational self-interest against the benefits of cooperation), and the Cournot duopoly (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover both simultaneous and sequential games and become familiar with a variety of concepts such as strict and weak dominance, randomization, expected utility maximization, never-best responses, non-credible threats, and time discounting. We'll also study solution concepts such as Nash equilibrium, correlated equilibrium, rationalizability, and subgame perfect equilibrium. Throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop. Some experience with mathematical methods (definitions, proofs, etc.) will be helpful.

80-306 Decision Theory

Spring: 9 units

Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the Prisoner's Dilemma (pitting rational self-interest against the benefits of cooperation), and the Cournot duopoly (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover both simultaneous and sequential games and become familiar with a variety of concepts such as strict and weak dominance, randomization, expected utility maximization, never-best responses, non-credible threats, and time discounting. We'll also study solution concepts such as Nash equilibrium, correlated equilibrium, rationalizability, and subgame perfect equilibrium. Throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop. Some experience with mathematical methods (definitions, proofs, etc.) will be helpful.

80-310 Formal Logic

Fall: 9 units

Among the most significant developments in modern logic is the formal analysis of the notions of provability and logical consequence for the logic of relations and quantification, known as first-order logic. These notions are related by the soundness and completeness theorems: a logical formula is provable if and only if it is true under every interpretation. This course provides a formal specification of the syntax and semantics of first-order logic and then proves the soundness and completeness theorems. Other topics may include: basic model theory, intuitionistic, modal, and higher-order logics.

Prerequisites: 15-251 or 80-210 or 21-127 or 80-211

80-311 Undecidability and Incompleteness

Spring: 9 units

U and λ ; I focuses on two fundamental results: the undecidability of logic (established by Alonzo Church and Alan Turing) and the incompleteness of mathematical theories (discovered by Kurt G and #246;del). The proofs of these results require a novel metamathematical perspective, but also striking logical concepts and fascinating mathematical techniques. In this course, the theorems are not just formulated but actually proved. We begin with the axiomatic development of elementary set theory that allows, at the same time, the formal representation of informal mathematics like number theory. With this basis, one can show that syntactic notions concerning set theory are representable in the very theory. It is then easy to prove that set theory is incomplete. To show that logic is undecidable, the crucial concept of computation is introduced via Turing machines. The two central concepts - proof and computation - are fundamental for mathematics, computer science and, in particular, artificial intelligence. The undecidability and incompleteness results are among the most significant contributions of modern logic to the foundations of mathematics. They provide also the beginnings of a deeper understanding of mental processes in cognitive science and, thus, of the human mind. To understand the latter connections, we will read about and discuss historical as well as philosophical aspects of the subject.

Prerequisites: 80-310 Min. grade C or 80-211 Min. grade C or 80-210 Min. grade B or 15-251 Min. grade C or 21-300 Min. grade C

80-312 Mathematical Revolutions

Spring: 9 units

Mathematics is a central part of our intellectual experience. It is connected to sophisticated philosophical perspectives, say, in the work of Plato, Descartes, Leibniz, Kant, as well as in contemporary analytic philosophy; it is equally connected to fundamental views in the sciences, say, in the work of Ptolemy, Galileo, Newton, Einstein, as well as in contemporary cosmology. The common view that mathematics - if not directly "static" - is evolving in a linear fashion, does not withstand historical scrutiny. Indeed, there are many dramatic conceptual changes concerning the very nature and object of mathematics.

80-315 Modal Logic

Fall: 9 units

Standard logical languages can express negation ("not p"), conjunction ("p and q"), material implication ("if p then q"), quantification ("for all x, p(x)", etc. But they don't directly capture statements like the following: "Alice knows p." "Henceforth, it will be the case that p." "It ought to be the case that p." "If it had been the case that p, it would have been the case that q." "Everybody knows p." "Everybody knows that everybody knows p." "Infinitely often in the future, p will be true." "After an announcement of p, it will be the case that Alice knows q." "If p is not permitted, then you ought to know that p is not permitted." etc. Modal logic is a very general framework for systematically reasoning about statements like these. This course is an introduction to mathematical modal logic and its applications in philosophy, computer science, linguistics, and economics, with emphasis on epistemic interpretations (i.e., logics for representing and reasoning about knowledge/belief). We begin with a rigorous development of propositional modal logic: the basic language, interpretation in relational structures, axiom systems, proofs, and validity. We prove soundness and completeness of various systems using the canonical model method and study model equivalence and expressivity results. We also consider topological semantics as an alternative to relational semantics, and investigate the connection between the two. In the latter part of the course we turn our attention to more specialized logical systems and their applications, as determined by the interests of the class. Topics may include: quantified modal logic, multi-agent systems and the notion of common knowledge (with applications to game theory), temporal and dynamic logics for (nondeterministic) program execution, logics for reasoning about counterfactuals, public announcement logic, deontic logic, intuitionistic logic, and others.

Prerequisites: 80-211 Min. grade C or 80-210 Min. grade C or 80-212 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C or 15-251 Min. grade C

80-316 Logic and AI

Intermittent: 9 units

In this course, we will study logical systems that are relevant to, and motivated by, research in artificial intelligence. We will see how key ideas and advances in logic have found (and continue to find) natural applications in AI. More generally, we will see how logic and AI can benefit, and historically have benefited, from each other. A central aim of this course is to understand how logical languages of varying expressive power can be put to use in AI as a tool for representation and reasoning. Some of the topics that we will be focusing on are (1) non-monotonic and default logics, (2) modal logics for reasoning about knowledge/belief, temporal structures, and computation, (3) probabilistic logics (and the relation between logic and probability), (4) logics of graphical causal models and counterfactuals, as well as (5) elements of probabilistic programming and computable probability theory.

Prerequisites: 80-310 or 80-610

80-321 Causation, Law, and Social Policy

Intermittent: 9 units

Policy makers face causal questions. For example, does violence on TV cause violence in life, and if so, what policies can we institute that will actually curb it? Does the death penalty actually deter criminals? Do tough drug laws reduce drug use? This course investigates how scientists establish causal claims, and how policy makers and the courts rely on or systematically ignore such science. We examine what causal claims mean and how they connect to statistical data, and we discuss the limits of standard techniques for establishing causal claims. We will consider all of these issues first theoretically, and then in the context of several case studies chosen mostly by the students.

Prerequisites: 36-200 or 36-201

80-324 Philosophy of Economics

Intermittent: 9 units

The science of economics has come to occupy a central position in contemporary society. Because of this central position in political decision making, economics is intertwined with a number of other philosophical issues surrounding justice, rights, and fairness. The central theme of this course will be on the arguments in favor and against markets as effective solutions to political problems. This issue will allow us to analyze a wide number of foundational issues in economics including the testability of economic claims, the use of "rationality" postulates, the foundation of the right to property, and measuring the success or failure of an economy.

80-325 Foundations of Causation and Machine Learning

Fall: 9 units

How can we define causality? Does smoking cause cancer? Can one find causality from observational data without temporal information? In our daily life and science, people often attempt to answer such causal questions for the purpose of understanding, proper manipulation of systems, and robust prediction under interventions. In the past decades, interesting advances were made in machine learning, philosophy, statistics, and economics for tackling long-standing causality problems, and a number of researchers have been recognized with the Turing Award (to Pearl in 2012) the Nobel Prize (to Granger in 2003 and to Sims in 2011). This course is primarily concerned with historical and technical developments of modern causality research, focusing particularly on how to discover causality from observational data and how to infer the causal effect of one variable on another. Thinking more broadly, causal analysis is a particular branch of unsupervised multivariate analysis. Accordingly, this course also provides a big picture of the foundations of causation and unsupervised machine learning. We start with unsupervised learning and multivariate statistical analysis problems including factor analysis, principal component analysis, and independent component analysis, and formulate their assumptions, develop their solutions, and study their connections with causal analysis. Finally, we investigate how the causal perspective helps in solving advanced machine learning or artificial intelligence problems, including transfer learning, image-to-image translation, reinforcement learning, and unsupervised deep learning.

80-326 Epistemology of Machine Learning

Intermittent: 9 units

Learning is hard! Programming a computer is also hard. Better that computers learn on their own from data how best to serve us. That is the goal of machine learning (ML), which is arguably the most successful branch of artificial intelligence. The very idea raises some natural, fundamental questions. What, exactly, is the goal of learning? Is it maintenance of consistency among our beliefs (Bayesian statistics), or is it a matter of estimating or predicting quantities in nature (frequentist statistics)? Is the goal prediction or truth; control or understanding; actual fact or necessary causal relations? Are predictions expected to be reliable beyond the narrow circumstances of training? Can learning be guaranteed to succeed by a specified time? Does success entail some detectable mark or sign of success that can be used to terminate the learning procedure? What roles do causality and simplicity play in learning, and how? Those questions arise spontaneously for the reflective ML researcher, but they also cross over into the foundations of statistics, the philosophy of science, and epistemology, the traditional philosophical study of the nature of knowledge and justified belief. This class provides an introduction to the relevant philosophical/foundational issues underlying ML research. It involves both philosophical reflection and exercises providing concrete experience with ML methods. A unifying theme is that strong definitions of successful learning imply correspondingly strong limits on what can be learned.

80-330 Ethical Theory

Spring: 9 units

This course provides a detailed survey of the structure of prominent theories of normative ethics. The space of possible consequentialist theories is surveyed in detail, allowing students to understand what distinguishes different forms of consequentialism and to assess the relative merits of these theories. The space of non-consequentialist theories is also surveyed, although in slightly less detail. The course engages classic texts from Aristotle, Kant and Mill and contemporary essays by leading philosophers.

80-334 Social and Political Philosophy

Intermittent: 9 units

Political philosophers are interested in whether, and to what extent, government use of coercion can be justified. This question involves many facets, including what gives the government the legitimate authority (if any) to coercively enforce the rules, what limits there are (if any) to the legitimate kinds of rules the government can enforce (and why), what obligations (if any) the government has to the citizens that are governed by its rules, and what claims (if any) citizens of a state can make upon one another. This course provides a systematic investigation of such questions as well as the concepts that are often appealed to in political theory, such as "justice," "equality," and "fairness." Readings will be comprised of classic and contemporary theorists from within the liberal political tradition as well as theorists critical of this tradition and its ability to live up to the lofty ideals it espouses.

80-335 Social and Political Philosophy

Fall: 9 units

Broadly speaking, political philosophers are interested in whether, and to what extent, government use of coercion can be justified, and how formal social and political institutions should be structured in order to be legitimate. Social philosophy encompasses these political questions, but also looks at how individuals should live together and how individual behaviors can impact not only state institutions but also more informal social norms and institutions. This is an advanced course in social and political philosophy, aimed at providing students with an in-depth familiarity with classic and contemporary questions both theoretical and applied.

80-336 Philosophy of Law

Intermittent: 9 units

In recent years, the U.S. legal system has been beset by claims of overcriminalization, racially discriminatory enforcement, and inadequate or unequal protection of individual civil rights. What should we make of these claims, and what, if anything, would be implied by their truth? In seeking to answer these questions, this course will examine the nature of the law and its enforcement. We will begin by discussing the issue of criminalization and whether the expansion of the criminal law is or is not problematic. From there, we will turn to the more foundational questions of what, precisely, the law is, and what its connection to morality is or should be. Are we obligated to obey the law, and if so, why? Finally, we will ask whether it is possible for the law to remain neutral with regards to morality and politics, and whether the supposed "neutrality" of the law may itself be an instrument of oppression. If the legal system lacks the kind of neutrality that many legal theorists claim for it, what (if anything) does that license us (as citizens) to do?

80-348 Health, Human Rights, and International Development

Fall: 9 units

Approximately 767 million people, or more than 10% of the world's population, live in a condition the World Bank refers to as "extreme poverty". Those who live in extreme poverty frequently lack effective access to proper nutrition, adequate shelter, safe drinking water, and sanitation. As a result, they also bear the greatest burdens of famine and epidemic disease and frequently face social and political conditions of unrest and systematic oppression. This course aims to introduce students to the problem of global public health and its intersection with claims of human rights. We will focus on theoretical accounts of human rights and questions arising from them: What constitutes a human right, and on what basis or bases might the existence of human rights be defended? If human rights exist, whose responsibility is it to see that they are defended/provided/not violated, and why? What is the relationship between health deficits and human rights deficits, and what would a "human right to health" look like? Are global institutions such as the protection of strong intellectual property rights consistent with respect for a human right to health?

80-350 Adam Smith

Intermittent: 9 units

Adam Smith is known as the father of economics. Many view Smith as a champion, not just of the science of economics, but of modern libertarian thought. His last book, *The Wealth of Nations*, is seen as the first defense of the value of free market capitalism. Less well known is Smith's earlier work which presents a altogether different picture. In it, Smith emphasizes the importance of altruism, empathy, and the value of interpersonal connection. In this course we will investigate the thought of Adam Smith, and find that he is far more complex than often portrayed.

80-358 Hume

Intermittent: 9 units

This course will investigate the philosophy of David Hume. We will focus on his philosophical thought expressed in the book *A Treatise of Human Nature*. Hume was an influential philosopher who wrote on many issues ranging from skepticism, to ethics, to the philosophy of science, and his views continue to be influential today. In this course we will attempt to understand Hume's philosophy on all of these subjects both to better understand his contribution to the philosophy of his day, but also to see what his arguments can contribute to contemporary thought.

80-365 Ramsey

Intermittent: 9 units

Frank Ramsey's untimely death in 1930, at the age of 26, marked the loss of a versatile and original thinker. During his short life, he made decisive and influential contributions to philosophy, mathematics and economics. The entire core of Ramsey's philosophical and scientific work consists of no more than 15 papers; in all cases they are remarkable essays that changed the intellectual topics they touched. This course will explore Ramsey's seminal contributions to probability and decision theory, philosophical and mathematical logic, the foundations of mathematics, metaphysics, and the philosophy of science. We will read some of Ramsey's original papers as well as more recent work inspired in response to, or as an elaboration on, Ramsey's views. We will see how Ramsey laid the foundations of the theory of subjective probability and decision theory, offered one of the first formulations of a deflationary theory of truth, and inspired contemporary work in philosophical logic (particularly on the logic of conditionals). We will explore Ramsey's influential work in the philosophy of science - his accounts of laws, causality, and the nature of scientific theories - as well as his mathematical contributions to logic and (what is now known as) Ramsey theory. By examining Ramsey's contributions and their impact, the course will give a sense of their important position as quintessential examples of work in the analytic tradition, demonstrating the intellectual fruitfulness of interdisciplinary inquiry into foundational questions and of mathematically informed philosophy.

80-380 Philosophy of Language

Intermittent: 9 units

Questions about language, meaning, and communication have a central place in both the history of analytic philosophy and the life of human societies. What do our words mean? What do we do by speaking them? What is the relationship between what our words literally mean and what we use them to communicate? What is it for a statement to be true but misleading? In what sense is it possible to experience a distinctively linguistic injustice? Should philosophers approach ordinary language as a cause of needless confusion, an indispensable source of insight, or both? In what ways is the study of language about the individual mind, in what ways is it about the speaker community? In spring 2020 this course will explore some major themes from the last century's debates in the philosophy meaning and communication, with attention to how these topics connect with social and political questions and with work in feminist philosophy. Students who do not meet the prerequisites but have an interest in the topic are strongly encouraged to reach out to the instructor about exceptions.

80-381 Meaning in Language

Fall: 9 units

One of the more elusive topics in the linguistics of natural language is meaning. This is the field of semantics. A key question to answer in semantics is what meaning even is. In this course, we will give an answer to this question, starting with the meaning of basic sentences. These are sentences that describe what is the case. From there, we break sentence meaning into the meaning of words. In the other direction, we consider the meaning of non-basic sentences such as questions and imperatives. We also consider the meaning of complex sentences and sentences that express irrealis. That starts with the subject of negation, with sentences that describe what is not the case. From there we move to sentences used to talk about what could be the case, what will be the case, what could've been the case, and what could never have been the case. A peculiarity of semantics is that the abstract questions we ask yield answers that are highly concrete and practical. But that only makes sense given that language permeates every human activity and it really matters what we mean by what we say.

Prerequisite: 80-180

80-382 Phonetics and Phonology II

Spring: 9 units

One of the central questions of research in human speech is how the patterning of speech sounds (phonology) relates to the articulatory, acoustics, and perceptual (phonetic) properties of speech; this problem is often referred to as the "phonetics-phonology interface". In this course, students will act as co-investigators on a topic at the phonetics-phonology interface, carrying out an acoustic study to test hypotheses that are relevant to phonological research. As co-researchers, students will be involved in all aspects of data collection and analysis. Lessons in phonetics will be designed to train students on the necessary skills and concepts required, including understanding the phonetic correlates of the phenomenon under investigation, as well as data analysis and interpretation of the results. A presentation session will be organized for the end of the semester. In tandem with the phonetic study, related phonological phenomena will be investigated throughout the semester. Students will finish this course with a solid understanding of how to do phonetic research, and an appreciation of how various theoretical frameworks have attempted to account for phonological phenomena. Assessment will take the form of quizzes, take-home problem sets, reflections on the research process, and a final report and presentation.

Prerequisites: 80-282 and 80-180

80-383 Language in Use

Fall: 9 units

In ordinary conversation, what a speaker conveys by the utterance of a sentence may go beyond, or be quite different from, the meaning that could be assigned to the sentence or expression that they use without consideration of the context in which it occurs. For example, the sentence "I have homework" means one thing; but it conveys something more when uttered in answer to the question "Do you want to go see a movie tonight?" In this course, we explore how the systematic study of linguistic meaning can be expanded from the domain of the sentence to the domain of connected, multiparty discourse. This involves taking into account the contributions of context, and of speaker and hearer's beliefs, goals and intentions, to the construction of meaning. This course is one of the set of courses on language and meaning offered by the Program in Linguistics, including in addition to this: 80-283 It Matters How You Say It, 80-288 Intonation, and 80-381 Meaning in Language. Each of these courses can be taken independently; as a set, these courses provide a comprehensive introduction to contemporary approaches to natural language semantics and pragmatics.

Prerequisites: 80-180 or 80-100

80-384 Linguistics of Turkic Languages

Intermittent: 9 units

In this course we look at languages from within a single language group, Turkic. Turkic languages are spoken across continental Asia and include such languages as Turkmen, Tatar, Kazakh, Uighur, and Uzbek. In this course we concentrate especially on Yakut (Sakha) and Azerbaijani. Modern Turkish will provide a reference language. We look at various linguistic systems within each language (phonology, morphology, syntax, and writing systems) both to understand each particular language and to see how the languages are related. We consider the impact of diachronic factors on the synchronic study of language. This course can be seen as an extended case-study for applying concepts and analytical strategies from basic linguistics, as taught in *Nature of Language*, *Phonetics and Phonology*, *Invented Languages*, and other relevant courses.

Prerequisite: 80-180

80-385 Linguistics of Germanic Languages

Intermittent: 9 units

The Germanic languages include English, Dutch, Frisian, German, Pennsylvanisch, Afrikaans, Yiddish, Icelandic and the Scandinavian languages, excluding Finnish. The course will serve as an extended case-study for the application of concepts and analytical strategies taught in basic linguistics courses to some of these languages. Specifically, we take a bottom-up approach to Dutch, Frisian, Icelandic, and Danish, starting with raw language material whenever possible, which we progressively analyze in terms of phonetics and phonology, morphology, and syntax. These case studies lead to comparisons between the languages and insight into their development and divergence over time. We follow this hands-on approach with historical and grammatical overviews, touching on some of the outstanding issues in Germanic linguistics. The approach should also help bring out the relevance of diachronic factors in the synchronic study of language, with historical forms of English being open to investigation, as these often reflect patterns found in contemporary Germanic languages.

Prerequisite: 80-180

80-388 Linguistic Typology: Diversity and Universals

Fall: 9 units

What is the most common word order? What is the rarest consonant? What kinds of case marking are attested in the world's languages? Which linguistic structures tend to co-occur? What can we learn by looking at the rarity of linguistic structures? These are the kinds of questions central to linguistic typology, the study and classification of languages based on their structural properties. In this course we will look at the variety of linguistic structures attested in several linguistic subfields, including phonology, morphology, syntax, and semantics. Understanding linguistic diversity is closely tied with the search for linguistic universals, since there appear to be some ways in which linguistic structures seem to be limited. But what is the nature of those limits (if they truly exist), and what do they tell us? We will also look at methodological issues that arise in comparing languages and forming meaningful generalizations. Prerequisites: 80-180, and one of 80-280, 80-282, 80-285 or permission of the instructor. Prerequisites: 80-180 and (80-285 or 80-280 or 80-282)

80-405 Game Theory

Spring: 9 units

Game theory is the study of interactive decision-making: making choices in the context of other agents who are also making choices. Famous examples include the "Prisoner's Dilemma" (pitting rational self-interest against the benefits of cooperation), and the "Cournot duopoly" (a basic model of market competition and supply-and-demand). Game theory has been applied to situations as diverse as traffic flow, auctions, the search and competition for scarce resources, and bargaining. This course will develop conceptual and technical facility with the mathematical tools used to model and analyze such situations. We will cover games in strategic and extensive form and games of perfect and imperfect information; we'll also study solution concepts such as Nash equilibrium and rationalizability. Finally, throughout the course we will take the opportunity to actually play several of the games we study to help build intuitions and foster insights into the formal mathematical models we develop.

80-411 Proof Theory

Intermittent: 9 units

An introduction to the general study of deductive systems and their properties. Topics include the natural deduction and sequent calculi; cut-elimination and normalization theorems; metamathematical properties of first-order logic and theories of arithmetic; and conservation theorems. Prerequisites: 80-310 or 80-311 or 21-300

80-413 Category Theory

Fall: 9 units

Category theory is a formal framework devoted to studying the structural relationships between mathematical objects. Developed in the mid-20th century to attack geometrical problems, subsequent progress has revealed deep connections to algebra and logic, as well as to mathematical physics and computer science. The course emphasizes two perspectives. On one hand, we develop the basic theory of categories, regarded as mathematical structures in their own right. At the same time, we will consider the application of these results to concrete examples from logic and algebra. Some familiarity with abstract algebra or logic required.

Course Website: <https://www.andrew.cmu.edu/user/jonASF/80-413-713/>

80-419 Interactive Theorem Proving

Intermittent: 9 units

Interactive theorem proving involves using computational proof assistants to verify that mathematical proofs are correct, or to verify that hardware and software designs meet their formal specifications. This course uses a new interactive theorem prover, Lean, to explore this new technology and its logical foundations. We will study dependent type theory, a powerful and expressive language for representing mathematical objects, algorithms, and proofs. We will also consider automated methods that can be used in support of formal verification, including propositional, equational, first-order, and higher-order methods, as well as decision procedures for real and integer arithmetic.

Prerequisites: 80-211 or 80-310 or 15-317 or 21-300

Course Website: https://leanprover.github.io/theorem_proving_in_lean/

80-445 Shift Capstone Experience

Spring

The Societal and Human Impacts of Future Technologies capstone experience will be taken in either the fall or spring of the senior year. It is required for all SHIFT minors. The purpose of the capstone experience is for students to demonstrate learning over time within the minor. Key learning experiences include incorporating concepts, ideas, and amp; frameworks from multiple disciplinary perspectives, using disciplinary perspectives in appropriate ways, given their complementary strengths and amp; weaknesses, generating a multidisciplinary (2) of some current or near-future technology, collaborating with people of different disciplinary backgrounds, and communicating a single, integrated analysis of the impacts and amp; opportunities of this novel technology (and amp; recommended actions). SHIFT minors should work with the minor advisor during the Spring of their junior year to design an appropriate capstone experience.

80-447 Global Justice

Spring: 9 units

Until recently, the dominant view of international relations has been that the governments and citizens of one country have no moral obligations to those beyond their borders. With the rapid growth in globalization has come a drastic shift in attitudes about our obligations to those with whom we share global institutions of trade but neither legal systems nor national identities. This course aims to introduce students to the problem of global distributive justice in the context of a globalized world, with emphases on both theoretical accounts of justice and the practical implications of those accounts for important current issues. Theoretical topics will include the nature of justice, the sources and limits of our moral obligations, and how and whether those notions of justice extend to global society; while applied topics will include our obligations with regard to the environment, human rights deficits, the status of women, and global economic policy.

80-449 EHPP Capstone Course

Fall: 12 units

In this Fall 2023 capstone course, Ethics, History, and Public Policy majors will carry out a collaborative or individual research project that examines a compelling current policy issue that can be illuminated with historical research and philosophical and policy analysis. Students will develop an original research report based on both archival and contemporary data and present their results in a public forum at the end of the semester. Please note: this semester we are experimenting with a more flexible set of research options for EHPP students, rather than a single project topic that all students are required to work on. Collaborative projects in groups of 2-3 students are encouraged, but individual projects that integrate historical, ethical, and policy perspectives are permissible too.

80-484 Language and Thought

Spring: 9 units

The goal of this course is to provide students with the opportunity to creatively explore some difficult questions about the relationship between language and thought, questions such as: How does the human capacity to use language relate to the human capacity to think? Does the language that a person speaks affect the way she thinks? If meaning is in the head, how can we succeed in communicating with each other? How is our ability to reason related to our ability to successfully communicate? None of these questions have definite answers; throughout the course, we will draw on work in philosophy, psychology and linguistics to try to understand some of the possible answers that might be entertained. Students in the course should be prepared for extensive reading, writing and peer discussion assignments.

80-488 Acoustics of Human Speech: Theory, Data, and Analysis

Spring: 9 units

In this course, students will learn how to acoustically analyse human speech, and in so doing, will learn about both universal and language-particular acoustic characteristics of human speech. The class, which will comprise both lectures and a lab component, will introduce the basic principles of the physics of sound and how the source spectrum is modified by the vocal tract, but the focus throughout will be towards developing a solid understanding of how to perform the relevant analyses. Each week will introduce a new topic, chosen to exemplify a particular acoustic phenomenon. Lectures for that week will provide the theoretical basis for understanding the phenomenon, both in terms of acoustic theory and in articulatory terms. The lab for that week will provide students with relevant acoustic data to analyse using PRAAT, an open-source software used for acoustic analysis. Potential topics include: What does it mean to say someone speaks with "vocal fry", and how do we measure this? Why do children replace [r] with [w]? How can we compare sounds in two different languages? For example, what are the acoustic characteristics of [r] and [l] in English and Japanese, such that these sounds count as two different sounds in English, but are so similar in Japanese? What makes an [s] so noisy compared to an [f]? What happens to speech sounds when we talk quickly, or when we're sick and our nose is stuffed up? At the conclusion of the course, students will have a solid understanding of the acoustic characteristics of human speech, both in terms of the underlying theory and how to measure such phenomena. Further, they will be able to translate questions about speech into measurable acoustic variables. There is no prerequisite for this course. While technical material will be covered, no background in linguistics, acoustics, physics, or math is assumed, and all required skills will be taught as needed.

80-495 Independent Study

All Semesters

Undergraduate Independent Study Philosophy Department majors.

80-500 Undergraduate Internship

All Semesters

Undergraduate Internship for Philosophy Department majors.

80-501 Undergraduate Research in Philosophy

Fall and Spring

This course is for students pursuing a research project under the supervision of a faculty member in the Philosophy Department. Time commitments as well as specific requirements, expectations, and deliverables of the research experience must be worked out in advance between the student and the supervising faculty member. The units can vary depending on the scope of the project.

80-514 Categorical Logic

Spring: 9 units

This course focuses on applications of category theory in logic and computer science. A leading idea is functorial semantics, according to which a model of a logical theory is a set-valued functor on a category determined by the theory. This gives rise to a syntax-invariant notion of a theory and introduces many algebraic methods into logic, leading naturally to the universal and other general models that distinguish functorial from classical semantics. Such categorical models occur, for example, in denotational semantics, e.g. treating the lambda-calculus via the theory of cartesian closed categories. Higher-order logic is treated categorically by the theory of topoi. We shall see how this idea connects logic with topology (the models of a theory form a space). A prerequisite for this course is familiarity with basic category theory (as treated in the course 80-413/713). Prerequisites: 80-413 Min. grade C or 80-713 Min. grade C

Course Website: <https://www.andrew.cmu.edu/user/awodey/catlog/>**80-516 Causality and Machine Learning**

Fall: 9 units

In the past decades, interesting advances were made in machine learning, philosophy, and statistics for tackling long-standing causality problems, including how to discover causal knowledge from observational data, known as causal discovery, and how to infer the effect of interventions. A number of researchers have been recognized with the Turing Award (to Pearl in 2012) the Nobel Prize (to Granger in 2003 and to Sims in 2011). Furthermore, it has recently been shown that the causal view may facilitate understanding and solving various machine learning or artificial intelligence problems such as transfer learning, semi-supervised learning, disentanglement, and adversarial vulnerability. This course is concerned with understanding causality, learning causality from observational data, and using causality to tackle a class of learning problems. We will particularly focus on two key problems in causality. One is causal discovery. It is well known that "correlation does not imply causality," but we will make this statement more precise by asking what assumptions, what information in the data, and what procedures enable us to successfully recover causal information. Causal influences may take place between the underlying hidden variables, and what we measure may be their reflections; so we will also see how to find the underlying hidden "causal" variables as well as their causal relations by analyzing measured variables. Its implication in unsupervised deep learning will be discussed. The other is how to properly make use of causal information. This includes identification of causal effects, counterfactual reasoning, improving machine learning in light of causal knowledge, and forecasting in complex environments, and we will investigate how the causal perspective helps in domain adaptation, image-to-image translation, and deep reinforcement learning.

80-517 Seminar on Topics in Logic: Algorithmic Randomness

Intermittent: 9 units

What is randomness? One way to think about it is as a property of sequences of, say, events, experimental outcomes, observations, or symbols from some alphabet: a sequence is random if it is unruly, irregular, patternless. This conception of randomness plays a significant role in a variety of fields, including cryptography, information theory, the foundations of probability and statistics, computability theory, and certain computational models of learning. To build some intuition, consider the two binary strings 0010111110 and 0101010101. The first string seems more random-looking than the second. This is because the second string displays an obvious pattern that is very easy to describe and that makes it look highly predictable. But can these intuitions be made precise? Is it possible to provide a rigorous mathematical characterization of the notion of a random sequence? This seminar will provide an introduction to the theory of algorithmic randomness, an active branch of computability theory according to which a sequence is random if it does not display any algorithmically detectable patterns. We will begin by discussing von Mises' theory of collectives, a precursor to the theory of algorithmic randomness; then, we will see how von Mises' work led to the modern computability-theoretic approach to randomness. We will focus on both the mathematical details of the theory of algorithmic randomness and its philosophical consequences. We will pay special attention to the connections between randomness, probability, and the philosophical interpretations of probability. Among the questions that we will address are: What is the relationship between probability and randomness? Is probability more primitive a concept than randomness, or is a precise analysis of randomness needed to understand what probabilities are? Is it possible to define "absolute" randomness? Does randomness have to satisfy any laws?

80-518 Seminar on Topics in Logic

Intermittent: 9 units

Topic: Introduction to Homotopy Type Theory Homotopy Type Theory (HoTT) is a new field of mathematics that extends Martin-L and #246's dependent type theory by the addition of the univalence axiom and higher inductive types. In HoTT we think of types as spaces, dependent types as fibrations, and of the identity types as path spaces. We will see that many spaces that are familiar to topologists can be represented as higher inductive types, and we will develop the basic theorems and constructions in HoTT to reason about them.

80-521 Seminar on Formal Epistemology: Belief and Evidence

Spring: 9 units

There has been a flurry of recent work on a variety of modal logics designed for reasoning about knowledge, belief, and evidence, in both static and dynamic contexts. What is the relationship between knowledge and belief? What is the role of evidence and justification? How do we react to new information, update our beliefs, and reason conditionally? These are old questions which modern logical frameworks promise to shed new light on. In this seminar we will read and analyze contemporary papers on these topics, both to gain an understanding of the current state-of-the-art, and to critically assess the extent to which these formal frameworks are genuinely enhancing our understanding of the underlying phenomena of interest.

80-524 Topics in Formal Epistemology: Topological Philosophy of Science

Intermittent: 9 units

When faced with a question concerning learning or scientific method, one habitually reaches for logic and probability theory. But sometimes habits should be questioned. There is increasing awareness, scattered across philosophy, informatics, mathematical statistics, that the relevant issues are more fundamentally topological. That may sound shocking: what could rubber geometry have to do with learning or inductive inference? The answer is that the set of empirically verifiable propositions over a set of possibilities automatically satisfies the axioms of a topological space over possible worlds. Once that is recognized, there is a systematic translation between topology and familiar concepts and issues in learning, statistics and the philosophy of science. This seminar will introduce the relevant topological concepts and will explore the methodological correspondences in detail. Topics covered include Hume's problem of induction, the problem of non-refutable theories and paradigm choice, convergence to the truth, simplicity and Ockham's razor, statistical model selection, causal discovery, and computability. The class will place students at the cutting edge of research in this fresh and exciting new area, and will provide them with a high-level, explanatory perspective that unifies much of the detail encountered in standard statistics and machine learning curricula.

80-551 Seminar on History of Philosophy: Smith and Hume

Fall: 9 units

David Hume and Adam Smith are the two most famous and influential figures of a philosophical era called the Scottish enlightenment. They had significant influences on one another and on the development of philosophy and the social sciences. In this class we will read work by both of them on topics related to ethics and the social sciences, and trace some of those ideas to modern philosophical and scientific ideas.

80-580 Seminar on the Philosophy of Language

Intermittent: 9 units

This course will provide an advanced level introduction to core topics and issues in contemporary philosophy of language and linguistic semantics. Readings will include both classic papers that provide the foundation of contemporary discussions (e.g. Frege, Kripke, Montague) and papers drawn from the contemporary literature. Possible topics include: reference and problems of reference (hyperintensionality and de se); modality; semantics of tense; introduction to formal semantic theory; compositionality; convention and linguistic meaning. This is a graduate level course. Interested undergraduates require permission of the instructor to enroll.

80-595 Senior Thesis

Fall and Spring

Philosophy Department majors writing a senior thesis, and are not participating in the Dietrich College Senior Honors Program, are given the opportunity to engage in original research under the direction of an individual faculty member. Research topics are selected by student.

Department of Psychology

Michael Tarr, Department Head

Erik Thiessen, Director of Undergraduate Education in Psychology

Chante Cox-Boyd, Associate Director of Undergraduate Education in Psychology

Emilie O'Leary, Academic Advisor in Psychology

Crista Crittenden, Academic Advisor in Psychology
www.cmu.edu/dietrich/psychology (<http://www.cmu.edu/dietrich/psychology/>)

Can newborn infants perceive the world as we do, or is it just "a blooming buzzing confusion"? Do personality, beliefs and social factors influence health? How do scientists and young children make discoveries, and what abilities make these insights possible? How does brain activity reveal differences in thinking? Can computers think the way people do?

These are some of the questions that psychologists at Carnegie Mellon are trying to answer.

For the student who is majoring in Psychology, Cognitive Science or Neuroscience, studying with faculty who are on the leading edge of research on questions like the above can be a very exciting experience.

The Psychology Department at Carnegie Mellon has long been noted as one of the pioneering Psychology Departments in the world, particularly in such areas as cognitive psychology, cognitive science, social psychology, developmental psychology, cognitive neuroscience, and health psychology. The Psychology Department offers 5 majors: B.A. and B.S. degrees in Psychology, as well as a B.S. degree in Cognitive Science and together with the Department of Biological Sciences, a unified B.S. double major in Psychology and Biological Sciences, and an Intercollegiate major in Neuroscience.

Statement of Community Standards

The Department of Psychology at Carnegie Mellon University strives to be a community that is academically and intellectually rigorous, as well as being diverse, inclusive, and respectful to all of its members. We aspire to promote a collegial professional environment in which all individuals can thrive and do their best work with community support and free from harassment, intimidation, or disrespect. We embrace and champion the following values:

Courtesy and Respect for Individuals

Excellence in the workplace requires an environment that promotes courtesy and civility towards every community member. Courtesy and civility require having mutual respect for one another. Therefore we expect all members of our community to take individual responsibility for:

- Viewing threats, hate speech, and harassment as totally unacceptable in an environment of free exchange of ideas amongst individuals.
- Encouraging all individuals to be respectful of others' views and opinions when expressing their own.
- Communicating with each other in ways that are clear, relevant, timely, constructive, and respectful.
- Making efforts to welcome and get to know all members of our community.
- Taking care of our common spaces rather than assuming that others will do it for us.

Diversity and Inclusion in Our Community

Academic excellence is built on a thriving and diverse community – something that is not possible without respectful treatment of all community members and intentional elimination of barriers to inclusion across groups. Therefore we expect all members of our community to take individual responsibility for:

- Providing mentoring and support for our colleagues.
- Prioritizing recruitment of people from diverse backgrounds into our community.
- Making efforts to be aware of the barriers faced by individuals and, whenever possible, making accommodations to remove or mitigate these barriers.
- Recognizing that with greater power within the academic hierarchy comes greater accountability for our actions and interactions.

- Making efforts to include our colleagues in intellectual and social gatherings during the workday whenever possible and appropriate.

The Major in Psychology

Psychology is a discipline that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think and behave through the scientific study of human behavior.

The orientation of the Carnegie Mellon Psychology curriculum is toward developing highly skilled and knowledgeable graduates. About half of our graduates go on to graduate or professional school. The remainder seek to expand their problem-oriented analytic skills to qualify themselves for job opportunities beyond those typically open to liberal arts students.

Using the outcomes tool (<https://www.cmu.edu/career/outcomes/post-grad-dashboard.html>) created by CMU's Career & Professional Development Center, students have the opportunity to explore where some of our recent graduates have accepted employment and their positions.

Majors in the department are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analysis, and writing reports. The department has many resources for students to use in acquiring these skills. For instance, students interested in child development may be involved in the child development laboratory and observational facilities which are a part of the Carnegie Mellon Children's School (<https://www.cmu.edu/dietrich/psychology/cs/>) which operates under the department's aegis. Students interested in health or clinical psychology might have opportunities to do internships in applied settings, and all Psychology majors have access to extensive computer facilities for data analysis and simulation work. The department also has a state of the art set of undergraduate research laboratories and computer clusters, and through the Scientific Imaging & Brain Research Center, a magnet is in use for conducting brain imaging studies using fMRI.

In addition to formal class work, students are encouraged to participate in research projects where they may register and receive credit for freshmen research experience course 85-198 Research Training: Psychology, 85-506 Readings in Psychology, Fall research experience in 85-507 Research in Psychology or Spring research experience in 85-508 Research in Psychology. In the research in psychology course, the student may work on an ongoing research projects or develop and carry out a new research project with a faculty member. To compliment students research experience, the department requires 85-509 Research in Psychology Practicum, a 1 unit, pass/fail course which provides students with an opportunity to frame their research experience in a broader professional and scholastic perspective. More information on research labs that are recruiting can be found here (<https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/research-opportunities/>).

There is university and departmental funding (<https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/undergrad-research-grants.html>) available to help support student-initiated research projects and student travel to present research results at scientific meetings and conferences. In the Readings courses, the student reads extensively on a particular topic. The faculty member and student meet to discuss the readings, and the student writes a paper on the topic selected. The Psychology Department Website (<http://www.cmu.edu/dietrich/psychology/>), provides descriptions of faculty research interests (<http://www.cmu.edu/dietrich/psychology/research-areas/>) that the student can use in determining who should be approached to supervise a particular research or reading project.

Students interested in gaining field work experience via a number of internship opportunities available to them can receive credit through 85-482 Internship in Psychology, 85-480 Internship in Clinical Psychology or 85-484 Practicum in Child Development. Clinical internships are available with a variety of clinical settings including the prestigious Western Psychiatric Institute (https://www.upmc.com/locations/hospitals/western-psychiatric/?gclid=aw.ds&utm_kxconfid=sws256pg0&utm_source=GOOGLE&utm_medium=cpc&utm_campaign=western+psychiatric&utm_advertiserid=700000001754524&gclid=EAlaIqobChMI-7Hg6vyD8gIVxdSzcH0) and Clinic (the teaching hospital of the Department of Psychiatry at the University of Pittsburgh Medical School). During the internship, students get first-hand experience with different clinical populations. Developmental

Practicum experience is available in the department-run CMU Children's School (<http://www.cmu.edu/dietrich/psychology/centers-and-facilities/>).

If you would like to learn more about the BA and BS in Psychology, please reach out to Crista Crittenden ccritten@andrew.cmu.edu for more information.

Bachelor of Arts in Psychology

Mathematics 10-20 units
21-111-21-112 Calculus I-II 20
or

21-120 Differential and Integral Calculus* 10

*Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement

Statistics Sequence 9 units

36-309 Experimental Design for Behavioral & Social Sciences 9
or 85-309 Statistical Concepts and Methods for Behavioral and Social Science

Psychology Surveys 27 units

85-102 Introduction to Psychology* 9

Survey Courses - Complete Two Units

85-104 Psychopathology 9

85-211 Cognitive Psychology 9

or 85-213 Human Information Processing and Artificial Intelligence

85-219 Foundations of Brain and Behavior 9

85-221 Principles of Child Development 9

85-241 Social Psychology 9

85-251 Personality 9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods 18 units

Complete two courses.

85-310 Research Methods in Cognitive Psychology 9

85-314 Cognitive Neuroscience Research Methods 9

85-320 Research Methods in Developmental Psychology 9

85-330 Analytic Research Methods 9

85-340 Research Methods in Social Psychology 9

Advanced Courses 18 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Psychology Breadth, Depth, and Application Electives 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300-85-499.

Exceptions for the course requirement

are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Application

85-198 Research Training: Psychology 9

85-294 Teaching Assistantship Var.

85-480 Internship in Clinical Psychology Var.

85-482 Internship in Psychology Var.

85-484 Practicum in Child Development Var.

85-507 Research in Psychology Var.

85-508 Research in Psychology Var.

85-601 Senior Thesis 9

85-602 Senior Thesis 9

66-501 Dietrich College Senior Honors Thesis I 9

66-502 Dietrich College Senior Honors Thesis II ^{Must} receive a B or higher, 9 units min 9

99-270 Summer Undergraduate Research Apprenticeship 9

Breadth

Any 200 level Psychology survey course.

85-104 Psychopathology 9

85-105 Hack Your Life 9

85-106 Animal Minds 9

85-107 The Psychology of Video Games 9

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please contact either Crista Crittenden ccritten@andrew.cmu.edu or Emilie O'Leary at emilier@andrew.cmu.edu.

Computer Science Requirement

15-110 Principles of Computing 10

or 88-300 Programming and Data Analysis for Social Scientists

or 15-112 Fundamentals of Programming and Computer Science

Natural Science Requirement (B.A. 18 units of which include 9 units of Gen Ed Science)

The B.A. in psychology requires one course beyond the General Education requirement in natural science.

These courses can be selected from the following areas:

- 03-XXX Biology*
- 09-XXX Chemistry
- 33-XXX Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take a course in Biological Sciences

Bachelor of Science in Psychology

Mathematics 10-20 units

21-111-21-112 Calculus I-II 20

or

21-120 Differential and Integral Calculus* 10

***Students who place out of 21-120 with AP credit will have successfully completed the calculus requirement**

Statistics Sequence 9 units

36-309 Experimental Design for Behavioral & Social Sciences 9

or 85-309 Statistical Concepts and Methods for Behavioral and Social Science

Psychology Surveys 27 units

85-102 Introduction to Psychology* 9

Survey Courses - Complete Two Units

85-104 Psychopathology 9

85-211 Cognitive Psychology 9

or 85-213 Human Information Processing and Artificial Intelligence

85-219 Foundations of Brain and Behavior 9

85-221 Principles of Child Development 9

85-241 Social Psychology 9

85-251 Personality 9

* Introduction to Psychology cannot be substituted; AP credit does not count towards this requirement

Research Methods 18 units

Complete two courses.

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

Advanced Courses 27 units

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-349. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Psychology Breadth, Depth, and Application Electives 27 Units

Three courses from at least two of the Breadth, Depth and Application Categories. Please Consult the psychology department undergraduate website for approved Breadth Electives.

Depth

Any Psychology course between 85-300-85-499. Exceptions for the course requirement are: 85-480, 85-482, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502.

Application

| | | |
|--------|---|------|
| 85-198 | Research Training: Psychology | 9 |
| 85-294 | Teaching Assistantship | Var. |
| 85-480 | Internship in Clinical Psychology | Var. |
| 85-482 | Internship in Psychology | Var. |
| 85-484 | Practicum in Child Development | Var. |
| 85-507 | Research in Psychology | Var. |
| 85-508 | Research in Psychology | Var. |
| 85-601 | Senior Thesis | 9 |
| 85-602 | Senior Thesis | 9 |
| 66-501 | Dietrich College Senior Honors Thesis I | 9 |
| 66-502 | Dietrich College Senior Honors Thesis II ^{Must receive a B or higher; 9 units min} | 9 |

Breadth

Any 200 level Psychology survey course.

| | | |
|--------|-------------------------------|---|
| 85-104 | Psychopathology | 9 |
| 85-106 | Animal Minds | 9 |
| 85-107 | The Psychology of Video Games | 9 |

or

Choose from a list of courses found outside of the department with departments including Biological Sciences, History, English, HCI, Philosophy, Social Decision Sciences and Statistics. The elective list may change and for the most up to date list please contact either Crista Crittenden ccritten@andrew.cmu.edu or Emilie O'Leary at emilier@andrew.cmu.edu

Computer Science Requirement 10 units

| | | |
|-----------|---|----|
| 15-110 | Principles of Computing | 10 |
| or 88-300 | Programming and Data Analysis for Social Scientists | |
| or 15-112 | Fundamentals of Programming and Computer Science | |

NATURAL SCIENCE REQUIREMENT (B.S. 27 UNITS OF WHICH INCLUDE 9 UNITS OF GEN ED SCIENCE)

The B.S. in psychology requires two courses beyond the General Education requirement in natural science.

- 03-xxx Biology*
- 09-xxx Chemistry
- 33-xxx Physics

* Given the growing relevance of biology to psychology, it is strongly recommended to take at least one course in Biological Sciences

Additional Major in Psychology

In order to complete an additional major in Psychology, a student must fulfill all of the Psychology major requirements within the department --

in other words, the breadth requirement, computing requirement, three survey courses, two research methods courses, and two advanced courses. These courses must include at least 81 units, plus calculus prerequisites and the 36-200 statistics course or equivalent and 36-309/85-309. In addition, psychology additional major candidates must complete one science course beyond the GenEd requirement if required for college.

Concentrations within the Psychology Major

Students who wish to focus their Psychology program on a specific area can do so either by the careful selection of Psychology elective courses focusing on their area of interest or by pursuing one of the following concentrations. Concentrations are not a required part of the major.

Please reach out to Crista Crittenden ccritten@andrew.cmu.edu to declare the concentration. The declared concentration will appear in Stellic. The completion of a concentration will be recognized in the Psychology Graduation Program.

Health-Psychology Concentration

For Psychology majors who wish to have a focus of their study on Health Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

| | | |
|---|--|-------|
| As part of the natural science requirement, choose two of the following | | Units |
| 03-121 | Modern Biology | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 03-135 | Structure and Function of the Human Body | 9 |

As part of the psychology breadth requirement:

| | | |
|--------|-----------------------------------|---|
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-241 | Social Psychology | 9 |

As part of the psychology Research Methods requirements:

| | | |
|--------|---------------------------------------|---|
| 85-340 | Research Methods in Social Psychology | 9 |
|--------|---------------------------------------|---|

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|---|---|
| 85-358 | Pro-Social Behavior | 9 |
| 85-422 | Clinical Psychology: Science and Practice | 9 |
| 85-442 | Health Psychology | 9 |
| 85-443 | Social Factors and Well-Being | 9 |
| 85-446 | Psychology of Gender | 9 |

As part of the Breadth, Depth and Application requirement, at least one of the following

| | | |
|--------|-----------------------------------|---|
| 85-480 | Internship in Clinical Psychology | 9 |
| 85-507 | Research in Psychology | 9 |
| 85-508 | Research in Psychology | 9 |
| 85-482 | Internship in Psychology | 9 |

or an additional advanced psychology seminar from the list above

Cognitive-Neuroscience Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Neuroscience, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

| | | |
|---|--|-------|
| As part of the natural science requirement, choose two of the following | | Units |
| 03-121 | Modern Biology | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |

As part of the psychology Breadth requirement:

| | | |
|--------|-----------------------------------|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

As part of the Research Methods requirement:

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|---|---|
| 85-351 | What is Attention? | 9 |
| 85-356 | Expertise: The cognitive (neuro)science of mastering almost any skill | 9 |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-370 | Perception | 9 |
| 85-382 | The Psychology and Neuroscience of Consciousness | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-432 | Data Science for Psychology and Neuroscience | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

As part of the Breadth, Depth and Application requirement, at least one of the following

| | | |
|--------|-------------------------------------|------|
| 85-507 | Research in Psychology | Var. |
| 85-508 | Research in Psychology | Var. |
| 88-342 | The Neuroscience of Decision Making | 9 |

Or an additional advanced psychology seminar from the list above

Learning and Developmental Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Behavior and Developmental Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement, choose one of the following

| | | |
|--------|--|---|
| 03-125 | Evolution | 9 |
| 03-121 | Modern Biology | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |

As part of the psychology Breadth requirement:

| | | |
|--------|---------------------------------|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-221 | Principles of Child Development | 9 |

As part of the psychology Research Methods Requirement:

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|--|---|
| 85-343 | Children, Race, and Racism | 9 |
| 85-351 | What is Attention? | 9 |
| 85-354 | Infant Language Development | 9 |
| 85-360 | Origins of Intelligence | 9 |
| 85-363 | Attention, Its Development and Disorders | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-394 | Development in Context: Applying Theory and Research to Support Thriving | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-418 | Infant development: Inside the mind of babies | 9 |

As part of the Breadth, Depth and Application requirement, at least two of the following

| | | |
|--------|--|------|
| 85-294 | Teaching Assistantship | Var. |
| 85-484 | Practicum in Child Development | Var. |
| 85-507 | Research in Psychology | Var. |
| 85-508 | Research in Psychology | Var. |
| 76-420 | The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process | 9 |
| 05-291 | Learning Media Design | 12 |
| 05-418 | Design Educational Games | 12 |
| 57-331 | Principles of Education | 9 |

Or an additional advanced psychology seminar from the list above

Cognitive Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Cognitive Psychology and/or Cognitive Modeling, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the B.S. science requirement:

| | | |
|--------|----------------|---|
| 03-121 | Modern Biology | 9 |
|--------|----------------|---|

As part of the psychology Breadth requirement:

| | | |
|--------|----------------------|---|
| 85-211 | Cognitive Psychology | 9 |
|--------|----------------------|---|

As part of the psychology Research Methods requirement:

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
|--------|--|---|

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|---|---|
| 85-351 | What is Attention? | 9 |
| 85-356 | Expertise: The cognitive (neuro)science of mastering almost any skill | 9 |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-360 | Origins of Intelligence | 9 |
| 85-363 | Attention, Its Development and Disorders | 9 |
| 85-370 | Perception | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-395 | Applications of Cognitive Science | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-421 | Language and Thought | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

As part of the Breadth, Depth and Application requirement, at least one of the following

| | | |
|--------|--|------|
| 85-507 | Research in Psychology | Var. |
| 85-508 | Research in Psychology | Var. |
| 76-420 | The Cognition of Reading and Writing: Introduction to a Social/Cognitive Process | 9 |
| 05-391 | Designing Human Centered Software | 12 |
| 05-413 | Human Factors | 9 |
| 80-305 | Game Theory | 9 |
| 80-380 | Philosophy of Language | 9 |
| 80-484 | Language and Thought | 9 |

Or an additional advanced psychology seminar

Social-Personality Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Social and/or Personality Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

As part of the Psychology Breadth requirement:

| | | |
|--------|-------------------|---|
| 85-104 | Psychopathology | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |

As part of the Psychology Research Methods requirement:

| | | |
|--------|---------------------------------------|---|
| 85-340 | Research Methods in Social Psychology | 9 |
|--------|---------------------------------------|---|

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|-------------------------------|---|
| 85-350 | Psychology of Prejudice | 9 |
| 85-358 | Pro-Social Behavior | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-377 | Attitudes and Persuasion | 9 |
| 85-442 | Health Psychology | 9 |
| 85-443 | Social Factors and Well-Being | 9 |
| 85-444 | Relationships | 9 |
| 85-446 | Psychology of Gender | 9 |

As part of the Breadth, Depth and Application requirement, at least one of the following

| | | |
|--------|--------------------------|------|
| 85-507 | Research in Psychology | Var. |
| 85-508 | Research in Psychology | Var. |
| 85-482 | Internship in Psychology | Var. |
| 05-320 | Social Web | 12 |

Or an additional advanced psychology seminar from the list above

Clinical/Counseling Psychology Concentration

For Psychology majors who wish to have a focus of their study be on Clinical/Counseling Psychology, the following courses should be selected as part of their Psychology Major in conjunction with their Psychology advisor's approval.

One of the following:

| | | |
|--------|--|---|
| 03-133 | Neurobiology of Disease | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 09-303 | Hooked: The Molecular Basis of Addiction | 6 |

As part of the Psychology Breadth requirement at least two of the following:

| | | |
|--------|---------------------------------|---|
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |

Required coursework:

| | | |
|--------|---|---|
| 85-104 | Psychopathology | 9 |
| 85-422 | Clinical Psychology: Science and Practice | 9 |
| 85-480 | Internship in Clinical Psychology | 9 |

As part of the Psychology Research Methods requirements at least one of the following:

| | | |
|--------|--|---|
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

As part of the advanced coursework in psychology requirement, at least two of the following:

| | | |
|--------|--|---|
| 85-343 | Children, Race, and Racism | 9 |
| 85-358 | Pro-Social Behavior | 9 |
| 85-363 | Attention, Its Development and Disorders | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-377 | Attitudes and Persuasion | 9 |
| 85-442 | Health Psychology | 9 |
| 85-443 | Social Factors and Well-Being | 9 |
| 85-444 | Relationships | 9 |
| 85-446 | Psychology of Gender | 9 |

Neuroscience Major

The Psychology Department at Carnegie Mellon University has a major focus on the role of the brain and nervous system in cognition and behavior, including biological approaches involving the health impact that arises from the interaction of behavior with the nervous, endocrine, and immune systems. These interests are manifested in faculty research (<http://www.cmu.edu/dietrich/psychology/research-areas/>), departmental and university centers that operate from or heavily involve the department (e.g., the Center for Cognitive Brain Imaging (<http://www.ccbi.cmu.edu/>), and the Center for the Neural Basis of Cognition (<http://www.cnbc.cmu.edu/>)) as well as undergraduate coursework (<http://www.cmu.edu/dietrich/psychology/undergraduate/>) and graduate coursework.

For undergraduates, there are a number of ways in which students with an interest in these approaches can pursue that interest in an organized fashion. Major requirements for the Bachelor of Science in Neuroscience can be found under Intercollege Programs (p. 890).

Carnegie Mellon University recently launched *BrainHub* – an initiative designed to leverage its core strengths in cognitive science, engineering, and computer science, and our emerging excellence in biological sciences, to harness the technology that helps the world explore brain and behavior. Students will be able to take advantage of exciting opportunities such as lectures hosted on various topics, newly funded CMU campus research projects trying to answer pressing questions in brain science and the many global partnerships with other institutions all with the same motivating goal to enhance and increase research in brain sciences.

Finally, for any interested student, there is a Minor in Cognitive Neuroscience (p. 502) available through the Psychology department.

The Major in Cognitive Science

The Psychology Department offers a B.S. degree in Cognitive Science. The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this major is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Cognitive Science Curriculum

The Cognitive Science major is only offered as a B.S. degree. Candidates should complete before the junior year the calculus requirement 21-120

(or alternatively 21-111/21-112) and a statistics sequence (36-200 or equivalent and if possible, 36-309/85-309). In addition, candidates complete 15-112 Fundamentals of Programming and Computer Science, as their departmental computing course.

Because of the number and sequential nature of required courses, prospective Cognitive Science majors are encouraged to begin course work for the major prior to junior year. In particular, completion of calculus, 36-200, and 85-211 or 85-213 before the junior year will enable students to complete one of the following 85-310/85-314/85-330 and 36-309/85-309 and by the Fall semester of their sophomore or junior year and, if interested, to then take advantage of research opportunities in the department. The Psychology Department (<https://www.cmu.edu/dietrich/psychology/undergraduate/current-students/research-and-internships/research-opportunities/>) website has more information regarding research for credit opportunities available to undergraduates.

Computing Prerequisite 10 units

| | | |
|--------|--|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
|--------|--|----|

Mathematics 29-30 units

| | | |
|---------------|---------------|----|
| 21-111-21-112 | Calculus I-II | 20 |
|---------------|---------------|----|

or

| | | |
|--------|--------------------------------------|----|
| 21-120 | Differential and Integral Calculus * | 10 |
| 21-127 | Concepts of Mathematics | 12 |

*Students who place out of 21-120 will have fulfilled the calculus requirement

Statistics Sequence 18 units

| | | |
|-----------|--|---|
| 36-200 | Reasoning with Data | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |

Computational/Cognitive Modeling Core 29-31 units

| | | |
|-----------------------|---|-------|
| Two of the following: | | Units |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Plus one of the following:

| | | |
|--------|---|---|
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

Cognitive Psychology Core 27 units

| | | |
|-----------|--|---|
| 85-211 | Cognitive Psychology | 9 |
| or 85-213 | Human Information Processing and Artificial Intelligence | |

Plus two of the following, one of which need to be 85-xxx:

| | | |
|--------|-----------------------------------|---|
| 85-219 | Foundations of Brain and Behavior | 9 |
|--------|-----------------------------------|---|

| | | |
|-----------|--|----|
| or 85-106 | Animal Minds | |
| or 80-180 | Nature of Language | |
| 85-351 | What is Attention? | 9 |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-370 | Perception | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-382 | The Psychology and Neuroscience of Consciousness | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-395 | Applications of Cognitive Science | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-421 | Language and Thought | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-310 | Formal Logic | 9 |
| 80-315 | Modal Logic | 9 |
| 80-383 | Language in Use | 9 |
| 05-413 | Human Factors | 9 |
| 11-344 | Machine Learning in Practice | 12 |

Cognitive Science Concentration

(3 courses, concentration approval required)

These three courses are chosen in conjunction with your advisor to form a coherent area of concentration from the course list under "Cognitive Science Concentration" in the current Undergraduate Catalog. Before proceeding with the choice of courses, students must fill out the concentration form, obtained from Emilie O'Leary in Baker Hall 339, with a description of the concentration area and the planned set of three courses. Courses not represented on the list may, with pre-approval of advisor and department, be used to satisfy part of this requirement. **The three courses are not required to be within any single category below but be coherent within the major and the focus may vary across disciplinary boundaries.** Courses taken for the major requirements can not be double counted in the concentration.

Computer Science

| | | |
|--------|---|----|
| 16-385 | Computer Vision | 12 |
| 15-453 | Formal Languages, Automata, and Computability | 9 |
| 15-213 | Introduction to Computer Systems | 12 |

Psychology

| | | |
|--------|---|---|
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-354 | Infant Language Development | 9 |
| 85-360 | Origins of Intelligence | 9 |
| 85-363 | Attention, Its Development and Disorders | 9 |
| 85-370 | Perception | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-395 | Applications of Cognitive Science | 9 |
| 85-406 | Autism: Psychological and Neuroscience Perspectives | 9 |
| 85-351 | What is Attention? | 9 |
| 85-356 | Expertise: The cognitive (neuro)science of mastering almost any skill | 9 |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-382 | The Psychology and Neuroscience of Consciousness | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-421 | Language and Thought | 9 |
| 85-423 | Cognitive Development | 9 |
| 85-426 | Learning in Humans and Machines | 9 |
| 85-429 | Cognitive Brain Imaging | 9 |
| 85-432 | Data Science for Psychology and Neuroscience | 9 |

Philosophy

| | | |
|--------|---|---|
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |

Human Computer Interaction

| | | |
|--------|--|----|
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-320 | Social Web | 12 |
| 05-333 | Gadgets, Sensors and Activity Recognition in HCI | 12 |
| 05-823 | E-Learning Design Principles and Methods | 12 |
| 05-433 | Programming Usable Interfaces OR Software Structures for Usable Interfaces | 6 |
| 05-418 | Design Educational Games | 12 |
| 05-413 | Human Factors | 9 |
| 05-410 | User-Centered Research and Evaluation | 12 |

Linguistics

| | | |
|--------|------------------------------------|---|
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-315 | Modal Logic | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |

Machine Learning

| | | |
|--------|--|----|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 10-335 | Art and Machine Learning | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 11-344 | Machine Learning in Practice | 12 |
| 11-411 | Natural Language Processing | 12 |

Decision Sciences

| | | |
|--------|--|----|
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-302 | Behavioral Decision Making | 9 |
| 88-355 | Social Brains: Neural Bases of Social Perception and Cognition | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-120 | Reason, Passion and Cognition | 9 |

Neurosciences

| | | |
|--------|--|----|
| 03-133 | Neurobiology of Disease | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 86-375 | Computational Perception | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 42-202 | Physiology | 9 |
| 15-386 | Neural Computation | 9 |
| 15-883 | Computational Models of Neural Systems | 12 |
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| 03-360 | Genomics and Epigenetics of the Brain | 9 |

Science Requirement

The Cognitive Science program requires two additional science courses beyond the college's one course Science General Education requirement.

These can be selected from any one of the following areas.

| | |
|--------|-----------|
| 03-xxx | Biology * |
| 09-xxx | Chemistry |
| 33-xxx | Physics |

* Those interested in a cognitive neuroscience focus are recommended to take biology courses, including if possible, 03-362, or 03-363.

Additional Major in Cognitive Science

In order to complete a double major in Cognitive Science, a student must fulfill the major requirements as listed under the Cognitive Science major. These include the programming requirement (15-112), the Mathematics and Statistics prerequisites, Computational/Cognitive Modeling Core, The Cognitive Psychology Core, the Cognitive Science Concentration Requirement, and the Supplementary Science Requirement. Students will be assigned a department advisor to help plan their program of studies in Cognitive Science.

Unified Double Major in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 321) and MCS (p. 582) are found on their respective Catalog pages.

Degree Requirements:

| Biological Sciences | | Units |
|----------------------------|--|-----------|
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 03-220 | Genetics | 9 |
| or 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 | Honors Biochemistry | 9 |
| 03-320 | Cell Biology | 9 |
| 03-343 | Experimental Techniques in Molecular Biology | 12 |
| 03-411 | Topics in Research | 1 |
| 03-412 | Topics in Research | 1 |
| 03-xxx | General Biology Elective ¹ | 9 |
| 03-3xx | Advanced Biology Elective ¹ | 18 |
| Total Biology units | | 78 |

¹ Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

| Mathematics, Statistics, Physics and Computer Science | | Units |
|---|--|--------------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-124 | Calculus II for Biologists and Chemists | 10 |
| or 21-122 | Integration and Approximation | |
| 36-200 | Reasoning with Data | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |
| 33-121 | Physics I for Science Students ² | 12 |
| or 33-141 | Physics I for Engineering Students | |
| 15-110 | Principles of Computing | 10-12 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| Total Science units | | 63-65 |

² MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

| | | |
|-------------------------------|---|-----------|
| Chemistry | | Units |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |
| Total Chemistry units | | 56 |
| Psychology Courses | | Units |
| 85-102 | Introduction to Psychology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-2xx | Survey Psychology Courses * | 18 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| or 85-314 | Cognitive Neuroscience Research Methods | |
| or 85-320 | Research Methods in Developmental Psychology | |
| or 85-330 | Analytic Research Methods | |
| or 85-340 | Research Methods in Social Psychology | |
| 85-3xx | Advanced Psychology Electives | 18 |
| Total Psychology units | | 63 |

* Excluding 85-261 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)

| | | |
|--------|------------------------------|---|
| 85-3xx | Advanced Psychology Elective | 9 |
| or | | |
| 03-3xx | Advanced Biology Elective | 9 |

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)

| | | |
|--------|--|----|
| 03-344 | Experimental Biochemistry | 12 |
| 03-345 | Experimental Cell and Developmental Biology | 12 |
| 03-346 | Experimental Neuroscience | 12 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

| | | |
|---|--|-------|
| Elective Units | | Units |
| Free Electives | | 33-36 |
| MCS Nontechnical Breadth or DC General Education requirements | | 36-48 |

Total Elective units 69-84

Minimum number of units required for degree: 360

Minors in Psychology and Cognitive Neuroscience

Minor in Psychology 72 units

I. Introductory course

| | | |
|--------|------------------------------|---|
| 85-102 | Introduction to Psychology * | 9 |
|--------|------------------------------|---|

*A survey course can be taken in place of 85-102.

II. Area Survey courses

Complete one course

| | | |
|-----------|--|---|
| 85-104 | Psychopathology | 9 |
| 85-211 | Cognitive Psychology | 9 |
| or 85-213 | Human Information Processing and Artificial Intelligence | |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-221 | Principles of Child Development | 9 |

| | | |
|-----------------|--|---|
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |
| III. Statistics | | |
| 36-200 | Reasoning with Data | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |

27 units Upper Level Courses

Complete three courses from categories IV and V, with at least one course from each.

IV. Research Methods Courses * (minimum 9 units)

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

* Prerequisites for all Research Methods courses: 36-309/85-309 and the appropriate survey course.

V. Advanced courses (minimum 9 units)

Advanced psychology courses exist within four areas (cognitive, cognitive neuroscience, developmental, social and health psychology.) Any advanced content course or seminar in psychology or any psychology course higher than 85-350. Exceptions for the advanced course requirement are: 85-480, 85-482, 85-484, 85-484, 85-506, 85-507, 85-508, 85-601, 85-602, 66-501, 66-502

| | | |
|--------|--|---|
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-382 | The Psychology and Neuroscience of Consciousness | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |
| 15-386 | Neural Computation | 9 |
| 86-375 | Computational Perception | 9 |
| 85-432 | Data Science for Psychology and Neuroscience | 9 |

Cognitive Neuroscience Electives

| | | |
|--------|--|---|
| 03-133 | Neurobiology of Disease | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 85-211 | Cognitive Psychology | 9 |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-360 | Origins of Intelligence | 9 |
| 85-370 | Perception | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-351 | What is Attention? | 9 |
| 85-106 | Animal Minds | 9 |
| 85-104 | Psychopathology | 9 |

Psychology Elective - Anything with 85-XXX number can be used 9 units

The Honors Program

The Honors Program provides recognition of outstanding performance by students in the Psychology department. Participation enables students to pursue their own research ideas through completion of an honors thesis. The honors thesis is completed during the senior year. By completing a thesis, the student earns 18 units of credit and qualifies for graduation with "College Honors." To qualify for the Honors Program, the student must maintain a quality point average of at least 3.50 in the major and 3.25 overall. More information on the Honor program can be found here (<http://www.cmu.edu/dietrich/undergraduate/programs/shp/>).

A year long departmental senior thesis course exists (66-501 and 66-502) for students interested in pursuing a sizable research project who do not qualify for the honors program. More information can be obtained by contacting Emilie O'Leary at emillier@andrew.cmu.edu.

Minor in Cognitive Neuroscience 63 units

The minor in Cognitive Neuroscience offered by the Department of Psychology is similar to the Neuroscience Minor offered by the Department of Biological Sciences. The differences between the two forms of the minor are determined by one required course, and additionally, by the students' choice of distribution electives. The requirements for the Cognitive Neuroscience Minor include 7 courses: four required courses, and three distribution and elective courses.

Because of the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience or Cognitive Neuroscience Minor requirements may count towards a student's major or other minor requirements.

Cognitive Neuroscience Curriculum

Required Coursework

| | | |
|-----------|-----------------------------------|---|
| 03-121 | Modern Biology | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| or 03-161 | Molecules to Mind | |
| 85-211 | Cognitive Psychology | 9 |

Distribution Requirements

Three courses, including at least 1 from each of the following categories

| | | |
|--------------------------------------|--|---|
| Approaches to Cognitive Neuroscience | | |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |

Faculty

JOHN R. ANDERSON, Richard King Mellon University Professor of Psychology and Computer Science - Ph.D., Stanford University; Carnegie Mellon, 1978-

JESSICA CANTLON, Ronald J. and Mary Ann Zdrojowski Associate Professor of Developmental Neuroscience - PhD, Duke University; Carnegie Mellon, 2007-

SHARON CARVER, Teaching Professor, Psychology; Associate Dean of Student Affairs, Dietrich College - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1993-

CHANTE COX-BOYD, Associate Teaching Professor - Ph.D., University of North Carolina at Chapel Hill; Carnegie Mellon, 1999-

DAVID CRESWELL, Professor - Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008-

KASEY CRESWELL, Associate Professor - Ph.D., University of Pittsburgh; Carnegie Mellon, 2012-

BROOKE C. FEENEY, Professor - Ph.D., State University of New York at Buffalo; Carnegie Mellon, 2001-

ANNA FISHER, Associate Professor - Ph.D., The Ohio State University; Carnegie Mellon, 2006-

VICKI S. HELGESON, Professor - Ph.D., University of Denver; Carnegie Mellon, 1990-

LAURIE HELLER, Teaching Professor - Ph.D., University of Pennsylvania; Carnegie Mellon, 2009-

MARCEL A. JUST, D. O. Hebb University Professor of Psychology - Ph.D., Stanford University; Carnegie Mellon, 1972-

ROBERTA KLATZKY, Charles J. Queenan Jr., University Professor of Psychology - Ph.D., Stanford University; Carnegie Mellon, 1993-

KENNETH R. KOEDINGER, Hillman Professor & METALS Program Director - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2001-

PHOEBE LAM, Assistant Professor - PhD, Northwestern University; Carnegie Mellon, 2023-

MARSHA C. LOVETT, Teaching Professor - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000-

BRIAN MACWHINNEY, Teresa Heinz Professor of Cognitive Psych - Ph.D., University of California, Berkeley; Carnegie Mellon, 1981-

BRADFORD MAHON, Associate Professor - PhD, Harvard University ; Carnegie Mellon, 2009-

KODY MANKE, Assistant Teaching Professor - Ph.D, Stanford University; Carnegie Mellon, 2016-

DAVID PLAUT, Professor of Psychology - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1994-

DAVID RAKISON, Associate Professor - D.Phil., University of Sussex; Carnegie Mellon, 2000-

MICHAEL TARR, Professor & Dept Head and Kavčič-Moura Professor of Cognitive and Brain Science - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2009-

ERIK D. THIESSEN, Associate Professor, Director of Undergraduate Education in Psychology - Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2004-

MICHAEL TRUJILLO, Assistant Professor - PhD, Virginia Commonwealth University; Carnegie Mellon, 2018-

TIMOTHY VERSTYNEN, Associate Professor and Co Director of the CMU-Pitt BRIDGE Center - Ph.D., University of California, Berkeley ; Carnegie Mellon, 2006-

Department of Psychology Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

85-102 Introduction to Psychology

Fall and Summer: 9 units

The world is a crazy, confusing place. Much of what we encounter is ambiguous, dynamic, and misleading. Somehow, we have to make sense of it. This class is about how we do that. The course provides an overview of the major areas of scientific psychology, exploring the models of our mind, brain, and behavior that explain wide areas of human (and non-human) functioning. Topics range from neuroscience and the biological basis of behavior, to memory and thought, to social interaction and psychological development over the lifespan, to abnormal psychology, psychopathology, and treatment. Tuesday and Thursday lectures provide a broad survey of topics and findings in psychology. In recitation sections students get hands on experiencing thinking about psychological science by designing and running psychological studies and discussing the real world implications of the concepts they have investigated. While all sections will be completing the same activities, some of the sections are themed. Themed sections will frame the discussion in the context of the theme, thus allowing students in those sections to better appreciate the links between the work being done in the class and the theme of that section. However, the core material will be the same and all sections will prepare students equally well for exams and upper division courses. General (unthemed) sections will sample across themes and topics, rather than being focused on a single theme. At the end of this course, students will not only be more knowledgeable about psychology, but be able to apply their knowledge about psychology to be better thinkers, learners, and consumers of information in general. Themed sections: Design - Register through Design Medicine, health, and Biosciences - Section I Decision Science, business, and economics - Section A

85-104 Psychopathology

Fall: 9 units

This course provides an introduction to the science and practice of psychopathology. Students will examine definitions of psychopathology in a historical and contemporary context, explore issues relevant to diagnosis and patient care, and be introduced to various diagnostic categories for psychological disorders. Students will also learn about potential determinants of and treatments for psychological disorders in the context of major theories and empirical findings in the field. Emphasis will be placed on three major paradigms in psychopathology: genetics, neuroscience, and cognitive behavioral. An assigned memoir, case studies, and short video clips will be used to illustrate the human side of mental illness.

85-105 Hack Your Life

Spring: 9 units

Hack your life! College offers a new opportunity to hack your life to explore who you are, how you learn, and how you can take better care of yourself. This course will give you the opportunity to fully explore the CMU student experience, the science of learning, and to explore issues central to students (e.g., resilience, social connections, mental health, sleep). Much of this course will focus on providing discussion, strategies, and practices around how you can live a better life, and nurture your happiness and health.

85-106 Animal Minds

Intermittent: 9 units

With intricate cultures, impressive technology, and layered social lives, humans seem to stand apart from their animal kin. However, humans and non-human animals share many aspects of their mental lives, and, upon closer inspection, some animals even reveal cognitive abilities far beyond the capacities of humans. Through comparing and contrasting human and non-human cognition, we can learn about human psychological uniqueness and its evolutionary origins, and fundamental properties of cognitive processes in general

85-107 The Psychology of Video Games

Intermittent: 9 units

This course will explore how the features of video game design and use relate to characteristics of human psychology. We will discuss design and use issues such as microtransactions, online gaming communities, and reward/scoring, and try to understand how these features are (or are not!) well suited to the human mind, with a particular focus on learning, memory, attention, and perception. Student presence will sometimes be required but many course sessions will be asynchronous.

85-120 Demystifying Freud and the Discipline of Psychology

Intermittent: 3 units

Regardless of discipline, an understanding of human thought and behavior is essential in navigating one's environment and work. Psychology, the science that can guide this understanding, is often misunderstood by the general public. Throughout the world, when psychology is mentioned, the name that often comes to mind is Sigmund Freud. Many of the misconceptions regarding psychology started with misinterpretations of Freud's work and concepts. Using Freud's most well-known concepts, this course will introduce students to what psychology is, and what it isn't - in hopes of illustrating what use psychological principles can be in a plethora of academic disciplines. In particular, students will learn how to apply these principles to modern day research settings with a specific focus on health and well-being research. Students will not only gain insight into their own academic and career paths, but into their own personality and health as well. Course work will consist of class attendance, weekly course readings and online discussions, one exam, and a final paper.

85-150 Cognitive Science at CMU and beyond

All Semesters: 9 units

This course provides an introduction to the broad field of Cognitive Science, with a particular emphasis on psychological methods and the role of memory in cognition. In addition to giving students a sense of some of the applied areas that use Cognitive Science research, this course gives a sampling of research questions and phenomena to help decide whether this might be a good choice for a major or minor while studying at Carnegie Mellon. Topics that will be discussed include attention, perception, cognitive illusions, memory, language acquisition and skill acquisition. There is an emphasis of the applications of cognitive science to real life situations, for example, best practices for learning in an academic setting. The course will also provide the opportunity to learn about the scientific method and collect data by running an experiment (online, on a computer). The class meets twice per week for 1.5 hours for each class. The plan is to focus more on lecture and discussion of readings on Tuesday and focus more on teaching new skills such as experimental design, data analysis and running experiments on Thursday.

85-198 Research Training: Psychology

Fall and Spring: 9 units

See course url and click on (forms and guides informational handout page) then click on current freshman-sophomore research training courses for listing of research training course descriptions.

Course Website: <https://www.cmu.edu/dietrich/students/undergraduate/programs/research-training-program.html>

85-202 Psychology and Society

Intermittent: 6 units

This course is based on the Inside-Out Prison Exchange Program, and will be taught at SCI Somerset, a nearby prison. For more information about Inside/Out see: <https://www.insideoutcenter.org/prospective-students.html> The course will include both "outside" students from CMU, as well as "inside" students at SCI Somerset. The course focuses on active participation and discussion between students. It runs from 2:30-5:10 on Friday afternoon. CMU students will travel together by bus, leaving our campus at 1:00 and returning by 6:30. To enroll, students in the course will submit a brief application and interview with faculty. The course is part of an exciting new initiative by CMU to bring education into America's prisons.

85-211 Cognitive Psychology

Fall and Spring: 9 units

This course focuses on the fascinating way that the brain processes the world and allows us to interact with it. Aside from covering the major topics in cognitive psychology (language, memory, visual processing, attention and cognitive control), it includes an introduction to some of the most recent approaches to studying human cognition. The course is set up to highlight the connection between cognitive studies and skills in various majors such as computer science, math, statistics, and medicine. It is also structured to foster the necessary skills for the critical analysis of complex problems.

85-213 Human Information Processing and Artificial Intelligence

Fall: 9 units

This course will review the information-processing challenges that humans face. We will discuss how these challenges are dealt with in the domains of attention, perception, memory, problem solving, reasoning, decision-making, and language. We will compare and contrast how these challenges are dealt with by humans and artificial intelligence applications. The course will include a number of programming projects that try to solve specific information-processing demands that occur in particular tasks and simulate human information processing. Student must have taken or currently be taking 15-122 or 15-150. If you will be taking 15-122 or 15-150 as a co req for this course, please contact Emilie O'Leary emilier@andrew.cmu.edu to be registered.

Prerequisites: 15-150 or 15-122

85-219 Foundations of Brain and Behavior

Fall: 9 units

This course provides a general introduction to the neural foundations of behavior. Topics will cover cognitive, perceptual, motor, social, and affective aspects of behavior. Each topic will be addressed at multiple scales, from single neurons and their interactions, to brain systems, to computational principles, and to real-world behaviors. While the focus will be on foundational principles and mechanisms (including some pretty cool case studies, illusions, anecdotes, etc.), there will also be some effort given to integrating current advances in computational cognitive neuroscience, including both the applications of modern AI to understanding biological systems and how principles drawn from biological systems might inform or improve artificial systems. Students are expected to regularly attend and participate in class.

85-221 Principles of Child Development

Fall and Spring: 9 units

This course is about normal development from conception through adolescence. Topics include physical, perceptual, cognitive, emotional and social development. Students will learn facts about children at various points in development, theories about how development works, and research methods for studying development in infants and children. Students will be encouraged to relate the facts, theories and methods of developmental psychology to everyday problems, social issues and real world concerns.

85-232 Thinking in Person vs. Thinking Online

Fall: 9 units

Being online changes how we think. Different media lead us to ask different questions, remember (or forget) different information, attend to different details, and interact with other people in different ways. These types of thinking aren't inherently better or worse, but they may be better or worse for facilitating specific goals. Too often, we use a particular medium/technology without considering how it will influence our thinking. This can lead us to be less efficient or less effective at a task than we otherwise might be, or can qualitatively change the nature of our outcomes. In this class, we will explore how the media we use affects the character of our thinking, so as to enable students to make mindful and deliberate choices about how to interact with media in ways that support the type of thinking desired and appropriate for their goals. Moreover, we will examine how to optimize media for specific goals in important applied domains, such as education, medicine, policy, child-rearing, and dating.

85-241 Social Psychology

Fall and Spring: 9 units

The focus of this course will be on how peoples behavior, feelings and thoughts are influenced or determined by their social environment. The course will begin with lectures and readings on how social psychologists go about studying social behavior. Next, various topics on which social psychologists have done research will be covered. These topics will include: person perception, prejudice and discrimination, the nature of attitudes and how attitudes are formed and changed, interpersonal attraction, conformity, compliance, altruism, aggression, group behavior, and applications of psychology to problems in health care, law, politics, and the environment. Through readings and lectures on these topics, students will also be exposed to social psychological theories.

85-250 Hack Your Life: The Science and Practices of Student Health and Well-Being

All Semesters: 9 units

College offers a new opportunity to hack your life to explore who you are, how you learn, and how you can take better care of yourself. This course will give you the opportunity to fully explore the CMU student experience, the science of learning, and to explore issues central to students (e.g., resilience, social connections, mental health, sleep). Much of this course will focus on providing discussion, strategies, and practices around how you can live a better life, and nurture your happiness and health.

85-251 Personality

Intermittent: 9 units

The primary purpose of personality psychology is to understand human uniqueness and #8212;how and why it is that one person differs from others, in terms of the ways that they thinks, feels, and acts. Students in the course will be exposed to several broad theoretical perspectives, each of which attempts to capture and understand the origins and consequences of individual distinctiveness from a slightly different vantage point. Included among these approaches are the dispositional or trait, psychoanalytic, learning, humanistic, and cognitive self regulation perspectives. This is a survey course and is intended to provide students with a broad background of theory and research in the area. Class meetings consist primarily of lecture, but there is some discussion too. Students will be given the opportunity to assess their own personalities during the course. A consistent theme throughout the course is the relationships between aspects of one's personality and physical health.

85-252 Intro to Health Psychology: SES and Health Inequalities

All Semesters: 3 units

Health Disparities exist in many countries around the world. For years researchers have sought to determine the root cause of these disparities and to explain why some people live significantly longer, healthier lives than others. Both mortality and morbidity rates can be related to ones' place in society and one's interactions with others. This course is designed to critically examine the social factors research has found to impact individual and population health experiences. We will focus specifically on those factors that comprise one's socioeconomic status. Students in the course will learn how money and access to health services are not the only factors that matters when it comes to one's health.

85-258 Intro to Health Psychology: Stigma and Its Consequences

All Semesters: 3 units

This course will introduce students to theoretical and empirical psychological research on prejudice and social stigma. The topics covered will include examinations of why individuals stigmatize: exploring cognitive, evolutionary, self, and system justification explanations. The course will examine the consequences of stigmatization for low-status groups (e.g., stereotype threat, dis-identification, internalization, health outcomes). We will explore the role of stigma in intergroup interactions and variation in the experience of stigma. Specific course topics will include the meaning of stigma, why people stigmatize, the physiological, cognitive-affective and social behavioral processes linking stigma and health outcomes, and moderators of stigma.

85-261 Psychopathology

Intermittent: 9 units

The study of psychopathology is not an exact science; nor are there many clear-cut parameters with which to differentiate "normal" and "abnormal" behavior. This course will focus on learning about and understanding the range of behaviors which fall within the province of "abnormal" psychology. Its approach will be descriptive, empirical, theoretical, and conceptual. Students will examine definitions of "abnormality" in a historical and contemporary context, explore issues relevant to diagnosis and patient care, be introduced to various psychological diagnostic categories, and develop an appreciation of the range of empirically-supported treatments for these disorders.

85-271 Animal Minds

All Semesters: 9 units

With intricate cultures, impressive technology, and layered social lives, humans seem to stand apart from their animal kin. However, humans and non-human animals share many aspects of their mental lives, and, upon closer inspection, some animals even reveal cognitive abilities far beyond the capacities of humans. Through comparing and contrasting human and non-human cognition, we can learn about human psychological uniqueness and its evolutionary origins, and fundamental properties of cognitive processes in general

85-281 Introduction to Clinical Psychology

Spring: 9 units

This course is designed to introduce students to a wide variety of concepts in the area of clinical psychology. We will explore clinical psychology in an historical perspective, ethics related to the practice of psychology, and various theories of psychotherapy (including psychoanalytic, psychodynamic, existential, and cognitive behavioral). Also, we will look at group theories underlying group therapy and family/systems therapy.

Prerequisites: 85-261 or 85-251

85-294 Teaching Assistantship

Intermittent

This course is designed to provide students with an apprenticeship in the practice of teaching through one-on-one interaction with a faculty member in the design, administration, and teaching of a course. The student should have previous coursework in the topic domain of the course to ensure that they have the basic skills and background necessary to contribute to the course. The Teaching Assistantship will be supervised by a faculty member, and should result in a concrete, measurable contribution to a course (such as the design of assignments or exams) and/or a reflection on the practical and pedagogical considerations of course design (such as a paper). It is the student's responsibility to make independent arrangement for independent course study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 9, depending on the amount of work done.

Course Website: <https://tinyurl.com/2encx2n3> (<https://tinyurl.com/2encx2n3/>)

85-309 Statistical Concepts and Methods for Behavioral and Social Science

Spring: 9 units

Research in the Social Sciences is a project of understanding the ways in which people are similar while grappling with the ways in which they are different. Statistical methods are a powerful tool for managing the tension between the two. This course introduces the statistical methods most commonly used in the social sciences, as well as their implementation in the R programming language. Topics involve exploratory data analysis, sampling and randomization, hypothesis testing, and power analysis.

Prerequisites: 36-200 or 36-201

85-310 Research Methods in Cognitive Psychology

Fall and Spring: 9 units

This is a course in which students develop the research skills associated with cognitive psychology and cognitive science. Students learn how to design and conduct experiments, and analyze and interpret the data they collect. The course covers a variety of experimental designs, e.g., factorial, Latin Squares. Analyses of response times, qualitative data, and signal detection are also covered. Cognitive modeling will also be discussed. Topics include mental imagery, memory, and perception. The class format consists of lectures, discussions and student presentations.

Prerequisites: (36-309 and 85-211) or (36-309 and 85-213) or (85-211 and 85-309) or (85-309 and 85-213)

85-311 Modern Research Methods: Cumulative Science, Big Data, and Meta-Analysis

Intermittent: 9 units

The scientific process is inherently cumulative: Scientific understanding moves forward by building on the theories, methods, and findings of individual scientists. The broad aim of this course is to teach you a set of practical, modern tools for conducting psychological research that facilitate cumulative scientific progress.

Prerequisites: (85-213 or 85-219 or 85-221 or 85-211 or 85-271 or 85-241 or 85-251 or 85-102 or 85-261) and (36-200 or 70-207 or 36-217)

85-314 Cognitive Neuroscience Research Methods

Intermittent: 9 units

This is a hands-on laboratory course designed to foster basic skills in the empirical approaches used in cognitive neuroscience research. Students will learn how to evaluate which cognitive neuroscience method is best suited to a research question, basic experimental design and analysis, and how to formally present empirical results. The course will focus on functional MRI, but will also cover structural MRI (diffusion imaging) and EEG, and survey various other methods. Students will work with actual datasets using the current software used by cognitive neuroscience researchers.

Prerequisites: (85-309 or 36-309) and (85-219 or 85-211)

85-316 Research Methods in Health Psychology

Spring: 9 units

TBA

85-320 Research Methods in Developmental Psychology

Fall and Spring: 9 units

This is a laboratory course, in which the student will have direct experience working with children, as well as writing research reports and designing and critiquing research in child development. The purpose of the course is to develop research expertise that will assist the student both in carrying out research and in evaluating the research of others. Special emphasis will be given to the unique methodological problems associated with the study of development. Students must be sure they are also available to attend the Children's School during specific blocks in addition to the class meeting times. Either MW 8:30-10:30am, TR 8:30-10:30am, MW 12:30-2:15pm or TR 12:30-2:15pm.

Prerequisites: (85-309 and 85-221) or (85-221 and 36-309)

85-330 Analytic Research Methods

Intermittent: 9 units

This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape

Prerequisites: 36-201 or 36-200

85-340 Research Methods in Social Psychology

Fall and Spring: 9 units

This course is designed to provide students with the necessary knowledge to evaluate research, make transitions between theory and the operations that test the theory, and to design and carry out original research. Topics will include the nature of proof and causal inference, manipulation of independent variables, measurement of dependent variables, questionnaire design, experimental, and quasi-experimental, design and ethical issues involved in doing research. Survey, observational and experimental techniques as applied in both field and laboratory settings will be covered. Students will be expected to criticize completed research. They are also expected to design measures and complete their own original studies. During the course of the semester students will also be expected to design and carry out an original research project as well.

Prerequisites: (85-251 and 36-309) or (36-309 and 85-241) or (85-241 and 85-309) or (85-309 and 85-241)

85-343 Children, Race, and Racism

Intermittent: 9 units

Millions of children grow up in racialized societies societies that are organized along racial lines historically, politically, and economically. How do children growing up in racialized societies come to understand race? How do children learn racism? How do children develop resilience in the face of racism? These are some of the questions we will address in this course through a combination of reading primary empirical and theoretical articles in psychology and class discussion.

Prerequisites: 85-102 or 85-211 or 85-221 or 85-219 or 85-241 or 85-251 or 85-104

85-345 Meaning in Mind and Brain

Intermittent: 9 units

What does it mean to say that an object, word, event or sentence means something? What is the nature of semantic representations that are activated in the brain during comprehension, and how are they related to perceptual, linguistic, mnemonic and motor representations? How do these representations emerge over the course of development, and how can they be selectively impaired by brain damage? This course examines these and related questions by drawing on findings from a broad range of methodologies, including developmental studies of young children, behavioral studies of adults, neuropsychological studies of brain-damaged patients, neurophysiology and functional brain imaging, and computational modeling. The course will take a seminar format in which students read, present and discuss the current literature.

Prerequisites: 85-219 or 85-211 or 85-213

85-350 Psychology of Prejudice

Spring: 9 units

This course is devoted to the study of both traditional and more modern forms of prejudice and discrimination and the psychological processes that can arise from categorizations and stereotyping. The class provides an overview of the cognitive and emotional underpinnings of prejudice and discrimination as it pertains to many forms of inequality. Its goal is to examine social differences and social inequality in many areas of society. The psychological theories underlying these behaviors will be examined as well as their impact on the lives of stigmatized individuals. In addition to the traditional forms of prejudice based on such things as race, gender and age, other inequalities that result from less traditional groupings such as social class, appearance, and disability will be explored. Research on issues of social identity, intergroup relations and the reduction of prejudice will be examined through readings and class activities.

Prerequisite: 85-241

85-351 What is Attention?

Intermittent: 9 units

For over a century, scientists have claimed that no one knows what attention is yet the past half-century has seen over 40 thousand publications with "attention" in the title. What gives? The primary goals of this course are first to show that we know what attention is and second, to demonstrate how to construct an important type of explanation in cognitive science. We investigate classics in the field and engage cutting edge research, in psychology, neuroscience, and even philosophy. One project will be cleaning house (theory and concepts). At the same time, in identifying the functional nature of attention, we unify different levels of analysis to construct a comprehensive account of what attention is, linking behavior, algorithms and neuroscience. We use this account to tackle various issues: different targets and forms of attention, attention and memory, the difference between attention and priming, attention's relation to behavior, attention and consciousness, executive control, attention's dependence on reward and learning, the developmental biology of attention, disorders of attention, attention and expertise, attention and implicit bias among other topics. Attention forms the foundation of our understanding of many other areas (arguably, it forms the foundation of life). The course will be based on drafts of the forthcoming second edition of the instructor's book, *Attention* (Routledge, 2014). We will also, hopefully, have guest lecturers from outside of CMU.

Prerequisites: 85-211 or 85-219

85-352 Evolutionary Psychology

Intermittent: 9 units

This course will cover both the fundamentals of evolutionary psychology, including the theories of natural and sexual selection, with the overarching aim of providing an overview of the field at an advanced level. We will examine the relevance of evolutionary thinking to a range of psychological phenomena including problems of survival, long-term mating strategies, short-term sexual strategies, parenting, kinship, cooperative alliances, aggression and warfare, conflict between the sexes, and prestige, status, and social dominance. We will also examine evolutionary approaches to sensation and perception, development, consciousness, cognition, language, and abnormal behavior. Juniors and Seniors only or permission of instructor. Pre req: 85-102, 85-211, 85-221, 85-241 or 85-251

Prerequisites: 85-221 or 85-241 or 85-251 or 85-211 or 85-102

85-353 Mindfulness: Science and Practice

Intermittent: 9 units

This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.

Prerequisites: 85-320 or 85-314 or 85-340 or 85-310

85-354 Infant Language Development

Intermittent: 9 units

While adults struggle to learn languages, almost all infants acquire language with seemingly little effort. This course examines infants' learning abilities and language milestones with a focus on several different theoretical accounts of language development, and the way empirical data can be used to assess those theories. The course is reading intensive, and evaluation will be based on both written assignments and oral participation.

Prerequisites: 85-221 or 85-211

85-356 Expertise: The cognitive (neuro)science of mastering almost any skill

Intermittent: 9 units

Though some of us struggle to hold a phone number in memory long enough to dial, Lu Chao recited 67,890 digits of pi from memory in 2005. With effort and effective strategies, human perception and cognition can reach great heights. But, even without much intentional practice, most people effortlessly recognize lyrics from hundreds of songs and faces of thousands of people. How does the human brain develop expertise across domains as diverse as music perception and performance, memory, sports, face recognition, and skills like chess? How do experts 'hack their brain' to achieve unusual levels of performance? Is talent made, or is it inborn? Can we capitalize on cognitive science and neuroscience to become better at math, wine tasting, medical diagnosis, or computer programming? In this course, we will work together to answer these questions while learning how to critically evaluate, synthesize, and communicate peer-reviewed research.

Prerequisites: 85-219 or 85-211

85-357 Navigating Race and Identity in America: The Role of Psychology in Racial Interactions

Intermittent: 9 units

How have social institutions and historical factors led to the belief systems and stereotypes that shape how race is experienced in American society, and how do these belief systems affect the way individuals within racial groups come to view and define themselves? This course will serve as an introduction to how people's psychology how they think, feel, and act shapes their experience of race and identity in America. After a brief discussion about the structural and systemic origins of the racial status quo, we will examine the way that individuals navigate the social and racial landscape of modern-day America. Complementing courses that take sociological approaches to race in America, this course will focus on how individuals' perceptions and thoughts about the world affect how they interpret and respond to social situations. For example, the course will address: how stereotypes about one's race or identity can cause individuals to feel threatened, and can undermine health, feelings of belonging, and academic performance how an individual's concerns about the thoughts and beliefs of others can radically affect identity formation, particularly during adolescence how individuals have to navigate multiple cultural identities, especially as minority group members contending with mainstream ideas that differ from their own how majority group members (e.g., Whites) view their role in racial systems, and how they deal with concerns about being or appearing prejudiced how interventions can use social psychological concepts to mitigate negative outcomes of racial inequality We will then use our understanding of these concepts to examine and consider different racial situations throughout American society and to understand how individuals navigate and experience race and identity. Throughout the course, we will watch films, read literature, and analyze music and art that reflect the experience of race and identity.

85-358 Pro-Social Behavior

Fall: 9 units

This course is an advanced seminar that focuses on social psychological research involving the examination of pro-social behavior. A heavy emphasis will be placed on classic research on helping (which investigates how, when, and why we help strangers), as well as the wide body of literature on social support (which investigates how we help, and seek help from, those who are closer to us). Research on both help-seeking and help-provision will be covered, as well as the implications of this type of pro-social behavior for relationships and health. The course also will cover research on other types of pro-social behavior such as empathy, altruism, forgiveness, and cooperation. This is an advanced seminar in which you will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a topic of interest.

Prerequisites: 85-311 or 85-340 or 85-310 or 85-330 or 85-314 or 85-320

85-359 Introduction to Music Cognition Research

Intermittent: 9 units

This course explores the roles of cognitive processes in the experience of music with a focus on carrying out a collaborative laboratory project in order to understand first-hand the challenges of the experimental study of music. In readings, lectures, discussions, and demonstrations we will become acquainted with the relevant psychological theories of perception, memory and learning, and review and critically analyze selected experimental findings on the psychology of music. We will examine the use of psychological principles (e.g. Gestalt laws of perception, limitations on working memory, categorical perception, chunking, schemas, modularity) to explain musical phenomena. The emphasis will be on applying an experimental approach to music perception and cognition, but we will also consider ongoing debates about larger issues (such as music's adaptive value to the human species, and the determinants of musical taste).

Prerequisite: either Harmony 1 or Cognitive Psychology or introduction to psychology or an intro level statistics or by instructor permission.

Prerequisites: (85-102 and 36-200) or (36-200 and 85-211)

85-360 Origins of Intelligence

All Semesters: 9 units

The nature and origins of human intelligence is a much-debated topic. Questions about the evolution and development of intelligence in humans, how intelligence compares among animals, the basis of intelligence in the brain, how to create intelligence in machines, the role of genes and experience, and individual variability in intelligence are all areas of vigorous scientific inquiry. Popular "folk" views of intelligence (that may be misguided or incorrect) have shaped all levels of society from parenting to politics. There is no universally accepted definition of human intelligence but one conceptualization is "the ability to remember, reason, plan, and solve novel problems". This course will explore scientific and popular views of the origins of intelligence. The approach will be to read popular science articles and books that deal with intelligence in humans, animals, and machines and locate the primary scientific work on which those claims are made in order to evaluate the rigor and validity of intelligence theories. The course assignments will primarily consist of oral and written critiques of theories and data on the science of intelligence.

85-362 Seminar on Addiction

Intermittent: 9 units

This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.

Prerequisites: 85-314 or 85-340 or 85-310 or 85-320

85-363 Attention, Its Development and Disorders

Intermittent: 9 units

This seminar will discuss a broad range of topics pertaining to the study of human attention, including: theoretical frameworks and biological foundations of human attention; interrelationship between attention and other aspects of cognition (such as perception, memory, and executive functions); development of attention in infancy and childhood; biological and psychological foundations of attention disorders. Students will be expected to read original research articles, lead and participate in class discussions, and complete a term paper.

Prerequisites: 85-221 or 85-211

85-370 Perception

Fall: 9 units

Perception, broadly defined, is the construction of a representation of the external world for purposes of thinking and acting. Although we often think of perception as the processing of inputs to the sense organs, the world conveyed by the senses is ambiguous, and cognitive and sensory systems interact to interpret it. In this course, we will examine the sensory-level mechanisms involved in perception by various sensory modalities, including vision, audition, and touch. We will learn how sensory coding interacts with top-down processing based on context and prior knowledge and how perception changes with learning and development. We will look at methods of psychophysics, neuroscience, and cognitive psychology. The goals include not only imparting basic knowledge about perception but also providing new insights into everyday experiences.

85-375 Crosscultural Psychology

Intermittent: 9 units

Human beings share a common genetic inheritance, but our cultural institutions differ in a bewildering variety of ways. This course explores the many different cultural expressions of basic human cognitive and social abilities and needs. We will look at cultural variations in child rearing, mother-child attachment, language socialization, categorization, reasoning, problem-solving, architecture, music, politics, warfare, food-gathering, sex roles, mental disorders, and altered states of consciousness, all with the goal of understanding how the shape of social systems and symbolic expression reflects the economic and adaptive needs of the culture and its people. Among the approaches to these phenomena we will consider are symbolic interaction, cognitive anthropology, dialectic materialism, and modern ethnology.

Prerequisites: 85-241 or 85-251 or 85-261 or 85-198 or 85-219 or 85-221 or 85-211 or 85-100 or 85-102

85-377 Attitudes and Persuasion

Intermittent: 9 units

This advanced undergraduate course will focus on the topic of attitude change and how various persuasive techniques are used to shape human response. The dynamics of propaganda and what makes the techniques effective on social and consumer decisions will be addressed. The primary goals of the course are to 1) understand the dynamics of attitude change; 2) explore the mechanism by which attitude change techniques operate and 3) examine relevant theories and research in persuasion. Examples of topics covered include the origins of attitudes, how attitudes influence judgments, social power and attitude change, and how individual decisions are influenced by the mass media. Classic and contemporary research in the area of persuasion will be examined in the form of course readings and assignments.

Prerequisite: 85-241

85-380 In Search of Mind: The History of Psychology

Intermittent: 9 units

This course will focus on three aspects of the origin and growth of experimental psychology. The first is the prehistory of psychology, where the connection of the discipline to the development of modern science, and in particular, its origins in philosophy and physiology, is examined. The second focus of the course is on the different approaches and attempts to define the field that have contested for dominance during much of the life of the discipline. The final major focus of the course is on the modern period (roughly the last forty years) where the influences that brought about the modern counter-revolution in psychology will be examined, and where some conjecture about likely future directions will occur. Two prior courses in psychology.

85-382 The Psychology and Neuroscience of Consciousness

Intermittent: 9 units

This course will explore consciousness as a scientific problem. It aims to dispel obscurity and mystery to make clear how consciousness can be illuminated empirically and theoretically without losing site of the "phenomenal". We begin with isolating the basic phenomenon, delve into the conceptual and philosophical background dividing access from phenomenal consciousness, and discuss methods for tracking consciousness. We will then identify two clear questions about 'generic' and 'specific' consciousness. On generic consciousness, we shall explore a set of empirical theories of consciousness and the evidence that supports them. This will include recurrent processing theory, global workspace theory, and higher-order theory among others. On specific consciousness, we will look at neural correlates and experimental interventions to test causal claims about how consciousness arises from the brain, with specific emphasis on sensory consciousness and the role of information and representation. Special topics will likely include the attention in consciousness, consciousness and agency, vegetative state, unconscious sensory processing in normal and lesioned brains, split brain phenomena and abnormal consciousness in psychiatric disorders such as schizophrenia. If possible, we will have a few guest lectures by local experts.

Prerequisites: 85-213 or 85-211 or 85-219

85-385 Auditory Perception: Sense of Sound

Intermittent: 9 units

This course explores how our sense of hearing allows us to interact with the world. Students will learn about basic principles of sound, spatial sound, sound quality, hearing impairment, auditory perception, interactions with other modalities, and auditory cognition. Topics may also include musical acoustics, basic auditory physiology, sound-semantic associations, acoustic analysis, and sound-making gestures. We will consider not only simple laboratory-generated signals, but also more complex sounds such as those in our everyday environment, as well music and speech. Students will gain some in-class experience with generating sounds and analytic listening. After students reach a sophisticated level of understanding of the auditory fundamentals, they will apply their knowledge to the study of several current issues in auditory research.

Prerequisites: 85-102 or 85-211

85-391 Psychology of Sleep

Intermittent: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. This course is an advanced seminar that focuses on the biology, psychology, and social factors of sleep and dreaming. The course will go over the history behind the scientific study of sleep, as well as the cultural and psychological underpinnings of dreaming. Students will also delve into the neuroscience and abnormal psychology of sleep. Emphasis will be placed on reading, presenting and analyzing empirical research articles. Students will also be required to fill out sleep logs and a dream diary, culminating in a final research paper analyzing their semester long sleep patterns and dreams based on research discussed in class.

Prerequisites: 85-102 and 85-211

85-392 Human Expertise

Intermittent: 9 units

The process of becoming an expert involves many changes, some quantitative and some qualitative. This course will provide an up-to-date account of the theory and data concerning the development of expertise. Questions addressed include the following. What does it take to become an expert? Are experts born or made? Is the process of acquiring expertise common across different domains from music to sports to science?

Research studied in the course will employ a variety of methodologies, from case studies to protocol analysis to computational modeling.

Prerequisites: 85-211 or 85-213

85-393 Memory: Models & Mechanisms

Intermittent: 9 units

This course will provide a basic understanding of human memory, covering both the many phenomena that have been studied over the years and also how theories have placed these phenomena within a general human cognitive system. The course will treat data and theory as equally important. Theory without empirical evidence is vacuous. Data without an explanatory mechanism is also unsatisfying. The course will cover many of the major principles of human memory starting with how information from the environment is encoded, processed and stored in memory. We will focus on how working memory (think of it as the Human CPU) affects how we encode and retrieve information from memory and what the limits are on this processing machinery. Theories of learning and the mechanisms involved in acquiring information as well as theories of forgetting will be examined in depth, along with variables that affect ease of encoding and obstacles to retrieval. The course will also focus on illusions of memory, how and why human memory is vulnerable to illusions and produces memory distortions. Most phenomena will be discussed in the context of theoretical explanations. Students will also learn about modeling approaches and how the various phenomena have been understood with different theoretical accounts. As a final project each student will develop a model to account for a phenomenon. This will either be fit to an existing body of data, or will take an existing theory, generate a new prediction based on that theory, and design an experiment to test whether the theory is supported or not (the experiment will not be run, but the design and predictions should be clear enough that it could be).

Prerequisite: 85-219

85-394 Development in Context: Applying Theory and Research to Support Thriving

Intermittent: 9 units

This course is an advanced seminar that focuses on synthesizing theory and research in developmental psychology and learning sciences so that proposed interventions to support children's development can be designed and evaluated. Theory and research relevant to cognitive, social emotional, and physical development can be applied to facilitate children's thriving in learning, belonging, mental health, and physical health, etc. Students will have an opportunity to select a particular age group and context for focus of independent literature review, a midterm interview project, and a final proposal for research-based intervention.

85-395 Applications of Cognitive Science

Spring: 9 units

The famous psychologist George Miller once said that Psychology should "give itself away." The goal of this course is to look at cases where we have done so and #8212; or at least tried. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se. That impact can take the form of a product, a change in practice, or a legal statute. The application should have a theoretical base, as contrasted, say, with pure measurement research as in ergonomics. Examples of applications are virtual reality (in vision, hearing, and touch), cognitive tutors based on models of cognitive processing, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students.

Prerequisites: 85-251 or 85-221 or 85-241 or 85-102 or 85-104 or 85-211 or 85-219

85-401 Introduction to Noninvasive Brain Imaging

Spring: 9 units

In the past the understanding of the brain's structure and function was limited by the need to access the brain via surgery and postmortem examination. In recent decades, advances in the fields of biology, psychology, physics, and engineering, have led to a slew of noninvasive methods for looking at the brain structure and function. These methods have become widespread in both clinical and research settings. This course will provide a survey of some of the most prominent of these neuroimaging methodologies, their advantages and disadvantages, and examples of their use. Topics covered include electroencephalography (EEG), computed tomography (CT), functional near-infrared spectroscopy (fNIRS), positron emission tomography (PET) and magnetic resonance imaging (MRI). Pre reqs listed or by permission of the course instructor.

Prerequisites: 03-151 or 03-121 or 85-219 or 85-102

85-402 Multilevel Modeling

Intermittent: 9 units

This course introduces a number of expressions of multilevel modeling that are now in common use in all the major branches of psychology, as well as in education and other sciences. The course balances conceptual understanding of MLM with practical, lab-based application. A working knowledge of R or SAS statistical software will be advantageous but not required.

Prerequisites: 85-309 or 36-309

85-406 Autism: Psychological and Neuroscience Perspectives

Fall: 9 units

Autism is a disorder that affects many cognitive and social processes, sparing some facets of thought while strongly impacting others. This seminar will examine the scientific research that has illuminated the nature of autism, focusing on its cognitive and biological aspects. For example, language, perception, and theory of mind are affected in autism. The readings will include a few short books and many primary journal articles. The readings will deal primarily with autism in people whose IQ's are in the normal range (high functioning autism). Seminar members will be expected to regularly enter to class discussions and make presentations based on the readings. The seminar will examine various domains of thinking and various biological underpinnings of brain function, to converge on the most recent scientific consensus on the biological and psychological characterization of autism. There will be a special focus on brain imaging studies of autism, including both structural (MRI) imaging of brain morphology and functional (fMRI and PET) imaging of brain activation during the performance of various tasks.

Prerequisites: 85-213 or 85-429 or 85-211 or 85-219 or 85-355

85-407 How the Brain Makes Meaning

Intermittent: 9 units

Conceptual knowledge underpins all aspects of everyday experience, from language, to thinking, to recognizing familiar objects, people and places. This seminar will survey major theories and findings about how the brain represents 'meaning.' The course will emphasize research using neuropsychological methods in brain-damaged patients and functional neuroimaging in healthy participants. Students will read primary empirical and theoretical review articles to develop an understanding of both classic findings and recent discoveries about how the human brain represents meaning.

Prerequisites: (85-211 or 85-219) and (36-200 or 36-201)

85-408 Visual Cognition

Intermittent: 9 units

Recognizing an object, face or word is a complex process which is mastered with little effort by humans. This course adopts a three-pronged approach, drawing on psychological, neural and computational models to explore a range of topics including early vision, visual attention, face recognition, reading, object recognition, and visual imagery. The course will take a seminar format.

Prerequisites: 85-211 or 85-213 or 85-219

85-409 Stigma and its Consequences

All Semesters: 9 units

This seminar will introduce students to theoretical and empirical psychological research on prejudice and social stigma. The topics covered will include examinations of why individuals stigmatize: exploring cognitive, evolutionary, self, and system justification explanations. The course will examine the consequences of stigmatization for low-status groups (e.g., stereotype threat, dis-identification, internalization, health outcomes). We will explore the role of stigma in intergroup interactions and variation in the experience of stigma. Specific course topics will include the meaning of stigma, why people stigmatize, the physiological, cognitive-affective and social behavioral processes linking stigma and health outcomes, and moderators of stigma.

85-412 Cognitive Modeling

Spring: 9 units

This course will be concerned with modeling of agent behavior in a range of applications from laboratory experiments on human cognition, high-performance simulations such as flight simulators, and video game environments. The first half of the course will teach a high-level modeling language for simulating human perception, cognition, and action. The second half of the course will be a project in which students develop a simulated agent or agents for the application of their choice.

Prerequisites: 15-251 or 15-150 or 15-210 or 15-122

85-414 Cognitive Neuropsychology

Spring: 9 units

This course will review what has been learned of the neural bases of cognition through studies of brain-damaged patients as well as newer techniques such as brain stimulation mapping, regional metabolic and blood flow imaging, and attempt to relate these clinical and physiological data to theories of the mind cast in information-processing terms. The course will be organized into units corresponding to the traditionally-defined subfields of cognitive psychology such as perception, memory and language. In each area, we will ask: To what extent do the neurological phenomena make contact with the available cognitive theories? When they do, what are their implications for these theories (i.e., Can we confirm or disconfirm particular cognitive theories using neurological data?)? When they do not, what does this tell us about the parses of the mind imposed by the theories and methodologies of cognitive psychology and neuropsychology?

Prerequisites: 85-219 or 85-211

85-418 Infant development: Inside the mind of babies

Intermittent: 9 units

This course will provide an overview of development in infancy with a focus on the emerging mind. A basic knowledge of developmental issues is assumed. We will cover the key aspects of infancy but with a primary focus on perception (seeing), cognition (thinking), and action (doing). Each week, students will be required to read a chapter in a textbook as well as short advanced empirical paper, often with conflicting accounts of a phenomenon. The instructor will introduce the key concepts, issues, and lines of research, but in each case students are expected to take an active role in discussing and developing ideas about the topic under consideration. Research methods specific to the study of infant development will be emphasized. Major issues that will be discussed include theories of developmental change, continuity in development, the nature of the psychological mechanism that underpin change, the relative contributions of heredity and environment, and the notion that all change occurs through a series of development cascades.

Prerequisite: 85-221

85-419 Introduction to Parallel Distributed Processing

Spring: 9 units

This course provides an overview of Parallel-Distributed-Processing/ neural-network models of perception, memory, language, knowledge representation, and learning. The course consists of lectures describing the theory behind the models as well as their implementation, and their application to specific empirical domains. Students get hands-on experience developing and running simulation models.

Prerequisites: 21-111 or 21-115 or 21-124 or 21-112 or 21-120

85-421 Language and Thought

Intermittent: 9 units

This course allows the student to explore ways in which the mind shapes language and language shapes the mind. Why are humans the only species with a full linguistic system? Some of the questions to be explored are: What kinds of mental abilities allow the child to learn language? What are the cognitive abilities needed to support the production and comprehension of sentences in real time? How do these abilities differ between people? Are there universal limits on the ways in which languages differ? Where do these limitations come from cognition in general or the specific language facility? Why is it so hard to learn a second language? Are there important links between language change and cultural change that point to links between language and culture?

Prerequisites: 80-180 or 80-150 or 85-211 or 85-213

85-422 Clinical Psychology: Science and Practice

Spring: 9 units

In this course, students will be exposed to the science and practice of clinical psychology, with a particular emphasis on the synergistic relationship between clinical psychological research and clinical practice. We will focus on the four major activities that clinical psychologists engage in (research, assessment, diagnosis, and psychotherapy). Students will learn about the clinical characteristics of major psychological disorders and the empirically-validated treatments available for these conditions. We will make frequent use of research findings and the scientific method to evaluate and understand concepts in clinical psychology. Critical thinking will be emphasized as we explore the scientific strengths and limitations of various treatments for psychological disorders. This course is designed to be a smaller seminar course for juniors and seniors considering graduate school in clinical psychology.

Prerequisites: 85-104 or 85-310 or 85-320 or 85-314 or 85-261 or 85-340

85-423 Cognitive Development

Intermittent: 9 units

The general goals of this course are that students become familiar with the basic phenomena and the leading theories of cognitive development, and that they learn to critically evaluate research in the area. Piagetian and information processing approaches will be discussed and contrasted. The focus will be upon the development of children's information processing capacity and the effect that differences in capacities have upon the child's ability to interact with the environment in problem solving and learning situations.

Prerequisite: 85-221

85-424 Hemispheric Specialization: Why, How and What?

Intermittent: 9 units

The brain is divided into two hemispheres, raising a host of questions about brain organization, hemispheric specialization and laterality. Despite all the research devoted to these questions, our understanding of the behavioral significance and neural basis of laterality remains limited. This course will address the questions of "why", "how" and "what". We will review the latest data and empirical results but will also develop a coherent theoretical perspective, moving from molecular, genetic and evolutionary considerations to cognitive and clinical factors in the understanding of one of the most fascinating phenomena in neuroscience, neuropsychology, psychiatry, neurology, and cognitive sciences. In addition to tackling a major text in the field (The Two Halves of the Brain Edited by Hugdahl and Westerhausen), we will read the latest papers in the field. The class will be almost entirely discussion-based and students will be responsible for doing the readings ahead of time and being prepared for the discussion.

Prerequisites: 85-251 or 85-241 or 85-221

85-425 Child Psychopathology and Treatment

Intermittent: 9 units

The first half of this course will focus on understanding the etiology and epidemiology of child and adolescent psychopathology. Special emphasis will be placed on conditions that are first diagnosed during childhood (e.g., ADHD, Autism, Eating Disorders) as well as understanding how child and adult psychopathology differ. The second half of this course will focus on treatment interventions for youth with psychopathology. Students will learn about how interventions for adults with psychopathology are altered to be developmentally appropriate for children, and methods of intervention commonly used with children but less so with adults (e.g., family therapy, play therapy). For students who have completed abnormal psychology and the psychology breadth requirement but not the other course pre-requisite, 85102, please see Theresa Kurutz to register for this course in BH 343.

Prerequisites: 85-261 and 85-102

85-426 Learning in Humans and Machines

Spring: 9 units

This course explores how probabilistic methods can help to explain cognition and to develop intelligent machines. The applications discussed include perception, language, memory, categorization, reasoning, decision-making, and motor control.

Prerequisite: 15-112

85-427 Metacognition: thinking about one's own thinking

Intermittent: 9 units

The course focuses on understanding metacognition, the marvelous ability of humans to inspect, understand, and regulate their own cognition. How do we know what we do or do not know? How good are we at estimating the accuracy of our memories of the past? How about what we will remember or forget in the future? Can we use such knowledge to do better? The study of metacognition provides an answer to these and many more questions. In other words, metacognition is the path to better knowing yourself.

Prerequisites: 85-219 or 85-211

85-429 Cognitive Brain Imaging

Spring: 9 units

This seminar will examine how the brain executes higher level cognitive processes, such as problem-solving, language comprehension, and visual thinking. The topic will be addressed by examining what recent brain imaging studies can tell us about these various kinds of thinking. This new scientific approach has the potential of providing important information about how the brain thinks, indicating not only what parts perform what function, but also how the activity of different parts of the brain are organized to perform some thinking task, and how various neurological diseases (e.g. aphasia, Alzheimer's) affect brain activity. A variety of different types of thinking will be examined, including short-term working memory storage and computation, problem solving, language comprehension, visual thinking. Several different technologies for measuring brain activity (e.g. PET and functional MRI and also some PET imaging) will be considered, attempting to relate brain physiology to cognitive functioning. The course will examine brain imaging in normal subjects and in people with various kinds of brain damage.

Prerequisites: 85-211 or 85-213 or 85-412 or 85-414 or 85-419

85-432 Data Science for Psychology and Neuroscience

Intermittent: 9 units

This course will cover advanced topics in statistics and experimental design necessary for applied research in modern psychology, including information design, exploratory data analysis, data visualization, nonparametric statistics, data and inference errors (multicollinearity, overfitting, Simpson's and Robinson's paradox), sanitization (data anonymization, de-identification), and linear models (including conditional process models). Students will get hands on experience with simulating, analyzing, and visualizing data in the R statistical environment.

Prerequisites: 85-309 or 36-309

85-435 Biologically Intelligent Exploration

Intermittent: 9 units

Humans and other mammals exhibit a high degree of control when selecting actions in noisy contexts, quickly adapting to unexpected outcomes in order to better exploit opportunities arising in the future. This course will explore both the cognitive and neurobiological systems of adaptive decision-making, through a mixture of readings, lectures, and hands-on modeling projects (in Python and Matlab).

Prerequisites: (85-211 or 85-213) and (21-115 or 21-120 or 21-111)

85-438 Educational Goals, Instruction, and Assessment

Fall: 9 units

This course will meet in TQ 1308 The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, and high school will be discussed and related to the state and national standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, and relation to system-level policies. Assignments will emphasize linking goals - instruction assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. This course will meet in TQ 1308

85-442 Health Psychology

Intermittent: 9 units

This course is concerned with how behavior and psychological states influence the development of and recovery from disease. The class provides an overview of existing psychological and epidemiological data on the relationship between behavior and disease and addresses the issue of how behavior, emotion and cognition can influence the disease processes. Topics include: measures and concepts, stress and disease, stress and coping, personal control, helplessness and disease, social support and health, reactivity to stress, behavior and hypertension, coronary heart disease, infectious diseases and immune function, and the effectiveness of behavioral interventions in health.

85-443 Social Factors and Well-Being

Intermittent: 9 units

This course will focus on the role that our social environment plays in our feelings of well-being and in the maintenance of our mental and physical health. Topics to be discussed include marriage, widowhood, loneliness, social support, social participation, social aspects of personality (e.g., social anxiety, extraversion, agreeableness, and hostility), social stressors (betrayal and conflict), discrimination, and socioeconomic status. We will consider how each social factor develops, the extent to which we can alter it or its effects on our lives, and how it influences our overall well-being.

85-444 Relationships

Fall: 9 units

The primary goal of this course is to introduce you to social psychological theory and research on the topic of relationships. Although a variety of relationship phenomena will be discussed, a heavy emphasis will be placed on research that addresses fundamental processes in close relationships. The coverage of material will include a review of historical roots and classic approaches to the scientific study of relationships, as well as exciting new research and theory on particular subtopics. The majority of class time is spent discussing and evaluating recent research. Special emphasis also is given to learning and critically evaluating the methodological tools that are used to study close relationships. This is an advanced seminar in which students will be expected to read original research articles and chapters on assigned topics and come to class prepared to discuss the material. Readings will consist of theoretical and empirical articles from psychology journals and related sources. Additional course requirements will involve short, weekly writing assignments, student presentations of research articles, and a written research proposal. Over the course of the semester, students will design and carry out a small-scale, original investigation on a relationships topic of interest.

Prerequisites: 85-340 or 85-311 or 85-330 or 85-314 or 85-310 or 85-320

85-446 Psychology of Gender

Spring: 9 units

This course is devoted to the investigation of psychological gender rather than biological sex. That is, sex differences will be explored from a social psychological (e.g., socialization) perspective. Implications of both male gender role and female gender role in the areas of relationships and health will be the course focus.

Prerequisites: 85-241 or 85-251

85-480 Internship in Clinical Psychology

All Semesters

This course allows students to gain applied clinical experience in a mental health setting. Students will work alongside psychology professionals at designated field placements. This course is designed to help students apply and expand their knowledge of clinical psychology and to develop appropriate professional work standards. Students will spend the majority of their time (8 hours per week) in an applied clinical setting, with a one hour per week supervision meeting with Dr. Creswell. Instructor permission is required, 85-104 Psychopathology can be taken as either a pre req or a co req. Please contact Dr. Kasey Creswell.

Prerequisites: 85-104 Min. grade B or 85-261 Min. grade B

85-481 Seminar in Intervention

Intermittent: 9 units

This course is an introduction to the therapeutic process. Students will be introduced to a variety of therapeutic approaches and techniques (e.g. Solution-Focused, Cognitive, Client Centered, etc.) and will have the opportunity to learn the basic skills associated with each (e.g. Cognitive Restructuring, Mirroring, Empathic Highlighting, etc.). Instruction will entail a mix of discussion and demonstration, and there will be a heavy emphasis on in-class practice of these skills.

85-482 Internship in Psychology

Fall and Spring

The Internship in Psychology is designed to enable students to gain experience in professional settings related to their studies in Psychology and earn credit for the intellectual work involved. It is the students responsibility to locate an internship site and on-site supervisor, as well as to identify a CMU faculty sponsor. The student registers for the internship by submitting a completed internship form to Emilie O'Leary in Baker Hall 339.

85-484 Practicum in Child Development

Fall and Spring

This guided field experience is designed to help students deepen their understanding of developmental psychology by assisting in a preschool or kindergarten classroom and discussing the ways that their experiences relate to the theories they have learned previously and to new readings. Each student will individually schedule a consistent 6 hours per week helping in a Children's School classroom (preferably 2 or 3 chunks of time). Classroom duties will include working one-on-one and with small groups of students as they do puzzles, art projects, dramatic play, etc., as well as helping with snack, playground supervision, classroom cleanup, and storytime. Each student will be expected to keep a journal 1) relating general experiences to developmental theories and 2) documenting the development of a particular child during the semester. All students will meet for a 1 hour weekly discussion with the director. Discussion topics and related readings will be selected collaboratively, based on issues/questions raised by the group's observations and discussions. This course is typically 9 units, but may be negotiable between 3 and 9.

Prerequisite: 85-221

85-501 Readings in Developmental psychology

Intermittent: 9 units

tba please reach out to Emilie O'Leary emilier@andrew.cmu.edu

85-505 Readings In Psychology

All Semesters

As the name implies, the emphasis in the Reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by the instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Readings courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done.

85-506 Readings in Psychology

Fall and Spring

As the name implies, the emphasis in the reading course is on reading articles and books in some specified area. The students work in the course must lead to the production of a written paper which will be read by a psychology faculty instructor directing the readings. Often the reading is related to a research project which the student may wish to conduct. Reading courses have also been used to give students an opportunity to receive instruction in areas which are not included elsewhere in our course listing. The course may be taken for any number of units up to 9, depending upon the amount of work to be done. This course is special permission and can only be added in consultation with a psychology faculty member and registered by the Undergraduate administrator, Emilie O'Leary emilier@andrew.cmu.edu.

85-507 Research in Psychology

Fall

This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done. Please contact the CMU psychology faculty member you wish to work with to get approval to enroll then email Emilie Rendulic at emilier@andrew.cmu.edu in order to be registered for the course.

85-508 Research in Psychology

Spring

This course may include field study, applied work, or laboratory research. The student should have previous training in the basic research skills that will be used in his/her project, especially statistical methods and experimental design. Independent Research Projects will be supervised by a faculty member and must result in a written paper. It is the students responsibility to make arrangements for independent study courses with individual faculty members. This should be done the semester before a student wishes to register for one of these courses. The course may be taken for any number of units up to 12, depending upon the amount of work to be done.

85-509 Research in Psychology Practicum

Fall and Spring: 1 unit

All students registered for research units via 85-198 or 85-507/508 * to register, in addition, for this 1 unit course. This course will meet every other week (online, at a time to be determined by survey). This course will provide students with an opportunity to frame their research experience in a broader professional and scholastic perspective, as well as an opportunity to get feedback on ongoing research experiences. Topics to be covered include professional development, protections for researchers and participants (including Title IX), problem solving, and communication. Students will complete short homework assignments in relation to each topic as a way of maintaining engagement with the course materials, as well as brief written assignments reflecting on their research experience. Students will be connected with resources like the Global Communications Center and the Career and Professional Development Center to help students contextualize their research experience in ways that contribute to their ongoing professional aspirations.

85-601 Senior Thesis

Fall

This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,502) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-602 Senior Thesis

Spring

This course is intended for senior Psychology or Cognitive Science majors who wish to conduct a research project under the direction of a faculty advisor. The project topic is to be selected jointly by the student and the advisor. The project will culminate in a senior paper which will be presented to the Department Head at the end of Fall Semester. Prerequisite: Grade of B or better in a previous research course required to enter, grade of B or better in first semester of senior thesis course required to complete, and permission of instructor. A formal proposal is required in the first semester. This course differs from the Honors Thesis sequence (66-501,602) in that it does not require Honors standing in HSS (i.e., there are no QPA requirements). This course differs from Research in Psychology (85-507,508) in that the student's original contribution to the research is expected to be more substantial, and in that a final written report of the project is to be presented to the Department.

85-730 Analytic Research Methods

Intermittent: 12 units

This class will teach students how to apply six major non-experimental research methods used in analytic behavioral analysis. Protocol Analysis. This method is used to study patterns and changes in problem-solving and their matches to theoretical models, including computational models. Corpus Analysis. This method is used to isolate patterns of behavioral and communication usage and change, as revealed through the study of the world-wide web and large computerized databases such as CHILDES, TalkBank, or the British National Corpus. Tools here include text searches and data-mining. Conversation Analysis. This is a microanalytic method used to examine sequencing, repair, and orientation in closely transcribed recordings of spoken interactions, as made available through systems such as the CABank database, as well as recorded programs on YouTube and elsewhere. Coding Systems. This approach seeks to capture interactional and behavioral structures in writing, teaching, interview, and other interactions. Here, there will be a special emphasis on the coding of instructional interactions. Gesture Analysis. This microanalytic method seeks to track patterns in gestural and nonverbal communication, often in association with spoken messages. Profile Analysis. This approach studies differences across learners at various ages and ability levels and group differences involving aphasia, autism, stuttering, dementia, and other individual differences. Students will work with data already available from previous studies, and will also learn to collect their own new datasets. Although the data being examined have been generated through naturalistic processes, they can be analyzed quantitatively using time-series analyses, non-parametric statistics, error matrices, and neural network simulations. In these various analyses, we will also consider how behavioral patterns are shape

85-753 Mindfulness: Science and Practice

Intermittent

This course will focus on blending first-person experience with mindfulness practices (including mindfulness meditation) and learning about the scientific research on mindfulness. Students will engage in guided mindfulness exercises, develop a daily mindfulness practice, and try out different mindfulness training traditions. In addition, much of this course will be focused on applying a critical eye to the theory, measures, mechanisms, and effects of mindfulness (and mindfulness training interventions) across multiple domains cognition, social processes, behavior, biological mechanisms, and health. As such, this will be a small seminar course focused developing first-person experiences of mindfulness and on discussing the debates and opportunities related to the emerging science of mindfulness.

85-762 Seminar on Addiction

Fall: 9 units

This seminar will explore various topics central to the study of drug addiction, with a primary emphasis on psychological and neurobiological theories of drug addiction. We will also discuss research and clinical techniques related to the assessment, diagnosis, and treatment of substance use disorders and related problems. Emphasis will be on alcohol and tobacco, but other drugs will be discussed as well. The main course objective is to provide a unifying model for understanding the fundamental aspects of addiction.

85-765 Cognitive Neuroscience

Intermittent: 9 units

This course will cover fundamental findings and approaches in cognitive neuroscience, with the goal of providing an overview of the field at an advanced level. Topics will include high-level vision, spatial cognition, working memory, long-term memory, learning, language, executive control, and emotion. Each topic will be approached from a variety of methodological directions, for example, computational modeling, cognitive assessment in brain-damaged humans, non-invasive brain monitoring in humans, and single-neuron recording in animals. Lectures will alternate with sessions in seminar format. Prerequisites: Graduate standing or two upper-level psychology courses from the areas of developmental psychology, cognitive psychology, computational modeling of intelligence, neuropsychology or neuroscience.

85-793 Memory: Models & Mechanisms

Intermittent

This course will provide a basic understanding of human memory, covering both the many phenomena that have been studied over the years and also how theories have placed these phenomena within a general human cognitive system. The course will treat data and theory as equally important. Theory without empirical evidence is vacuous. Data without an explanatory mechanism is also unsatisfying. The course will cover many of the major principles of human memory starting with how information from the environment is encoded, processed and stored in memory. We will focus on how working memory (think of it as the Human CPU) affects how we encode and retrieve information from memory and what the limits are on this processing machinery. Theories of learning and the mechanisms involved in acquiring information as well as theories of forgetting will be examined in depth, along with variables that affect ease of encoding and obstacles to retrieval. The course will also focus on illusions of memory, how and why human memory is vulnerable to illusions and produces memory distortions. Most phenomena will be discussed in the context of theoretical explanations. Students will also learn about modeling approaches and how the various phenomena have been understood with different theoretical accounts. As a final project each student will develop a model to account for a phenomenon. This will either be fit to an existing body of data, or will take an existing theory, generate a new prediction based on that theory, and design an experiment to test whether the theory is supported or not (the experiment will not be run, but the design and predictions should be clear enough that it could be).

85-851 Personality and Health

Intermittent

The general purpose of this course is to examine possible connections between personality and physical well-being. Material will be presented at the outset of the semester that is designed to enable students to understand more fully how psychologists think about the concept of personality (what it is and what it does for us), how it is assessed, and how personality and health psychologists do research on the topic. As the semester progresses, we will explore and discuss research that links certain aspects of personality to health, illness, and mortality. The list of personality characteristics to be considered includes (but is not necessarily limited to) optimism/pessimism, conscientiousness, hostility, trait positive and negative affect, life purpose, and chronic goal adjustment strategies. As time permits, select person variables will also be considered, e.g., the impact of depressive mood on health. Class time will be largely taken by discussion of original research papers. Different sets of students will be responsible for leading these discussions. Grades will be based on a combination of class participation, quality of paper presentations, and performance on a final research paper.

Department of Social and Decision Sciences

Location: Porter Hall 208
www.cmu.edu/dietrich/sds (<http://www.cmu.edu/dietrich/sds/>)

The Department of Social and Decision Sciences is a multidisciplinary department that offers undergraduate programs that focus on decision making using a broad set of social science approaches. Theoretical and empirical work is seamlessly combined with the practical skills needed to excel in key decision making roles in the public, private, and non-profit sectors and in advanced graduate studies. Our students learn how to combine standards of rationality with the realities of human and organizational behavior and to apply these lessons across a wide variety of endeavors, ranging from government service to leadership positions consulting, marketing, data science, and other sectors.

The department offers undergraduate majors in Behavioral Economics, in Decision Science, and in Policy and Management. Each major includes a distinct set of required and elective courses. Course offerings leverage faculty strength in behavioral decision making, behavioral economics, and behavioral science approaches to public policy to produce a unique curriculum.

Our faculty is committed to the academic success and growth of our students and many of our undergraduates work with faculty on research projects and internships. The directors of the majors are easily accessible and encourage students to talk with them about their curriculum, progress, and available opportunities. Our academic advisors are committed to working with each individual student to help them create, clarify, and meet their goals.

The Department of Social and Decision Sciences has long been recognized as a global nexus of decision science expertise, offering undergraduate programs that are available at few other universities. Our cohesive majors combine theory and practice allowing our graduates to excel in a range of professions or in the pursuit of advanced studies.

The Major in Behavioral Economics

Peter Schwarzmann, *Faculty Director*
 Location: Porter Hall 223J
[schwarzmann](http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionssciences/schwarzmann@cmu.edu) (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionssciences/schwarzmann@cmu.edu>)@andrew.cmu.edu (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/departmentofsocialanddecisionssciences/schwarzmann@cmu.edu>)

Lizzy Stoye, *Senior Academic Advisor*
 Location: Porter Hall 208G
estoyle@andrew.cmu.edu
 Schedule an appointment: <https://go.oncehub.com/LizzyStoye> (<https://go.oncehub.com/LizzyStoye/>)

The field of Behavioral Economics (BE) integrates perspectives from Economics and Psychology to better understand how people make consequential decisions and to leverage this understanding to improve the design of the policies, programs, and institutions that govern such behavior. The last decade has witnessed an explosion of interest in BE among governments and organizations, around the world, including here in the United States. On the policy front, this has led to the formation of government “nudge” units charged with applying BE principles to policy areas such as education, criminal justice, taxation, social benefit programs, consumer protection, and unemployment. Organizations have also aggressively sought to apply BE to encourage employee productivity, improve employee health and financial wellness, reshape managerial and hiring decisions, and to better understand and engage consumers.

The faculty in the Department of Social and Decision Sciences (SDS) has long stood at the forefront of research and teaching in BE. Our faculty has developed a reputation for working closely with governments and firms to help apply BE to address a range of issues such as predatory lending and consumer protection, bias among institutional investors, employee reward and incentive programs, behavioral barriers to retirement savings, participation in social service programs, medical adherence, pre-trial detention of defendants, and gender and racial inequality in the workplace.

The new major of BE-- the first of its kind among US undergraduate institutions--was designed to rigorously train students in the field of Behavioral Economics and to encourage them to critically consider its

relevance to policy and organizations. The major emphasizes both theory and the practical promise of BE to solve problems of importance to policy makers and organizations through the largest undergraduate selection of BE courses of any university in the world. Towards this end, students will learn to collect original data, design field and laboratory experiments, analyze data and draw causal inferences, and develop interventions to improve economic outcomes and decisions. The core requirements include courses in Economics, Psychology, Behavioral Economics, and quantitative methods- including experimental design and econometrics. Students who complete the major will be well positioned to enter the private sector in a role involving data or people analytics, marketing, corporate strategy, or human resources, or to enter a wide range of graduate degree programs.

Prerequisites

All Behavioral Economics majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

| | |
|--|-------|
| Mathematics Prerequisite | Units |
| 21-111-21-112 Calculus I-II | 10-20 |
| or 21-120 Differential and Integral Calculus | |
| Statistics Prerequisite | Units |
| 36-200 Reasoning with Data | 9 |

Curriculum

The core curriculum in Behavioral Economics consists of three Behavioral Economics courses, two Economic courses, two Psychology courses, three quantitative courses, and one project course.

| | |
|--|-----------|
| Behavioral Economics Courses | Units |
| 88-360 Behavioral Economics | 9 |
| 88-365 Behavioral Economics and Public Policy | 9 |
| 88-367 Behavioral Economics & Field Experiments in Organizations | 9 |
| | 27 |

| | |
|---|-----------|
| Economics Courses | Units |
| 73-102 Principles of Microeconomics | 9 |
| or 73-104 Principles of Microeconomics Accelerated | |
| Second-Level Economics Course* | |
| 88-221 Markets, Democracy, and Public Policy | 9 |
| or 73-103 Principles of Macroeconomics | |
| or 73-158 Markets, Models, and Math | |
| or 73-230 Intermediate Microeconomics | |
| or 73-328 Health Economics | |
| or 73-347 Game Theory Applications for Economics and Business | |
| or 73-359 Benefit-Cost Analysis | |
| or 73-408 Law and Economics | |
| or 73-421 Emerging Markets | |
| or 73-427 Sustainability, Energy, and Environmental Economics | |
| | 18 |

* Second-Level Economics course CANNOT double count with the Economics Elective course.

| | |
|--|-----------|
| Psychology Courses | Units |
| 88-120 Reason, Passion and Cognition * | 9 |
| 88-302 Behavioral Decision Making | 9 |
| | 18 |

* 88-120 Should be taken in the first or sophomore year.

| | |
|--|-------|
| Quantitative Methods Courses | Units |
| 36-202 Methods for Statistics & Data Science | 9 |
| 88-251 Empirical Research Methods | 9 |

| | | |
|-----------|------------------|---|
| 88-252 | Cause and Effect | 9 |
| or 73-274 | Econometrics I | |

27

| | |
|--------------------------------------|-------|
| Senior Project Course | Units |
| 88-453 Behavioral Economics Capstone | 9 |

9**ELECTIVES 36 units**

Complete at least 27 units from the following categories. Students MUST take one elective from the Economics category, and another from the Behavioral Economics category. The third elective may be chosen from either the Behavioral Economics or Psychology categories. Note that not all elective courses are offered every year.

| Economics* | Units |
|--|-------|
| 73-103 Principles of Macroeconomics | 9 |
| 73-158 Markets, Models, and Math | 9 |
| 73-230 Intermediate Microeconomics ** | 9 |
| 73-328 Health Economics | 12 |
| 73-347 Game Theory Applications for Economics and Business | 9 |
| 73-359 Benefit-Cost Analysis | 9 |
| 73-408 Law and Economics | 9 |
| 73-421 Emerging Markets *** | 9 |
| 73-427 Sustainability, Energy, and Environmental Economics | 9 |
| 88-323 Policy in a Global Economy | 9 |

* ANY 73-3XX or 73-4XX courses be counted as an economic elective course. Consult the Academic Advisor for more information about this process. NOTE: The Economics Elective course CANNOT double count with the Second-Level Economics core requirement.

** Requires additional Math beyond 21-112 or 21-120.

*** 73-421 has a required prerequisite of 73-103 Principles of Macroeconomics, which is NOT a course requirement for the BE major.

| Behavioral Economics | Units |
|--|-------|
| 88-255 Strategic Decision Making | 9 |
| 88-261 Health Policy | 9 |
| 88-275 Bubbles: Data Science for Human Minds | 9 |
| 88-300 Programming and Data Analysis for Social Scientists | 9 |
| 88-366 Behavioral Economics of Poverty and Development | 9 |
| 88-406 Behavioral Economics @ Work | 9 |
| 88-418 Negotiation: Strategies and Behavioral Insights | 9 |

| Psychology | Units |
|--|-------|
| 70-311 Organizational Behavior | 9 |
| 70-385 Consumer Behavior * | 9 |
| 70-443 Digital Marketing and Social Media Strategy | 9 |
| 85-350 Psychology of Prejudice | 9 |
| 85-352 Evolutionary Psychology | 9 |
| 85-358 Pro-Social Behavior | 9 |
| 85-375 Crosscultural Psychology | 9 |
| 85-377 Attitudes and Persuasion | 9 |
| 85-442 Health Psychology | 9 |
| 85-446 Psychology of Gender | 9 |
| 88-230 Human Intelligence and Human Stupidity | 9 |
| 88-231 Thinking in Person vs. Thinking Online | 9 |
| 88-312 Decision Models and Games | 9 |
| 88-342 The Neuroscience of Decision Making | 9 |
| 88-372 Social and Emotional Brain | 9 |
| 88-380 Dynamic Decisions | 9 |
| 88-388 Psychological Models of Decision Making | 9 |
| 88-419 International Negotiation | 9 |
| 88-435 Decision Science and Policy | 9 |

* 70-385 has a required prerequisite of 70-381 Marketing 1, which is NOT a course requirement for the BE major.

Note: Some courses have additional prerequisites.

Behavioral Economics, B.S. Sample Curriculum

| First-Year | | Second-Year | |
|---|--|---|--|
| Fall | Spring | Fall | Spring |
| 88-120 Reason, Passion and Cognition* | 36-202 Methods for Statistics & Data Science | 88-251 Empirical Research Methods | 88-252 Cause and Effect |
| 21-120 Differential and Integral Calculus | Second-Level Economics Course Pick One (88-221, 73-103, 73-158, 73-230 (requires Math beyond 21-112/21-120), 73-328, 73-347, 73-359, 73-408, 73-421, 73-427) | 88-360 Behavioral Economics | 88-302 Behavioral Decision Making |
| 36-200 Reasoning with Data | Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities) | 88-365 Behavioral Economics and Public Policy | 88-367 Behavioral Economics & Field Experiments in Organizations |
| 73-102 Principles of Microeconomics Or 73-104 Principles of Microeconomics Accelerated | Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities) | Gen Ed or Elective | Behavioral Economics Elective |
| Pick One (Grand Challenge Seminar, First Year Writing, Disciplinary Perspectives: Humanities) | Gen Ed or Elective | Gen Ed or Elective | Gen Ed or Elective |

| Third-Year | | Fourth-Year | |
|--------------------|---------------------|--------------------------------------|------------------------------------|
| Fall | Spring | Fall | Spring |
| Economics Elective | Psychology Elective | 88-453 Behavioral Economics Capstone | Elective or Senior Honors Thesis** |
| Gen Ed or Elective | Gen Ed or Elective | Elective | Elective |
| Gen Ed or Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

* Should be taken as the first course in Behavioral Economics major sequence. It is intended for students in their first or second year and is offered in both the fall and spring semesters. It may be taken as late as the junior year.

** Senior Honors Thesis may be substituted in the Spring term for 88-453 Behavioral Economics Capstone, which is only offered in the Fall term.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the first-year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Behavioral Economics Academic Advisor.

Additional Major

Students who elect Behavioral Economics as an additional major must fulfill all of the requirements of the Behavioral Economics major.

Additional majors cannot count BE electives toward simultaneously fulfilling requirements for another major or minor. Students who are interested in an additional major in Behavioral Economics should consult the Behavioral Economics Academic Advisor for guidance.

Students pursuing Decision Science with an additional major in Behavioral Economics may only count 36-202, 73-102, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Behavioral Economics may only count 36-202, 73-102 and 88-251 toward the completion of both majors.

The Major in Decision Science

Silvia Saccardo, *Faculty Director*
Location: Porter Hall 319C
DS-advisor@andrew.cmu.edu
ssaccard@andrew.cmu.edu

Lizzy Stoye, *Senior Academic Advisor*
Advises Primary Majors in Decision Science
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Connie Angermeier, *Senior Academic Program Manager*
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The interdisciplinary field of Decision Science seeks to understand and improve the judgment and decision making of individuals, groups, and organizations. Qualified graduates can continue to PhD programs in Decision Science or related fields (e.g., psychology, business), pursue professional degrees (e.g., MBA, MD, JD, MPH), or take professional positions in business, government, consulting, or the non-profit sector. Students work with faculty and the Academic Advisor to tailor their education to their personal needs and interest.

Carnegie Mellon is one of the leading centers for the study of Decision Science - and offers the only undergraduate major that integrates analytical and behavioral approaches to decision making. Our faculty are involved in applying Decision Science in a wide variety of areas, allowing them to share practical experiences with students. These applications include use of decision aids (e.g., effects on cognitive processes of using technology), medical decision making (e.g., harnessing decision principles to design interventions to promote healthy behavior), risk management (e.g., assessing and communicating the risks of climate change), marketing (e.g., understanding the effects of inter-temporal choice on purchasing decisions), and business (e.g., identifying unrecognized conflicts of interest).

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the major cover the three aspects of decision science: (a) normative analysis, creating formal models of choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, Decision Science majors gain broadly applicable skills in research design and analysis and in application of research findings to behavioral problems in consumer, organizational, and public policy arenas.

The core courses present fundamental theories and results from the study of decision making, along with their application to real-world problems. They introduce students to methods for collecting and analyzing behavioral data. For example, students learn to conduct surveys (e.g., uncovering consumer or managerial preferences), design experiments (e.g., evaluating theories, comparing ways of presenting information), and evaluate the effectiveness of interventions.

The elective courses provide students with additional knowledge in areas of decision making that meet their personal, intellectual, and career goals. These courses are organized into six clusters: biological and behavioral aspects of decision making, managerial and organizational aspects, philosophical and ethical perspectives, economic and statistical methods, public policy, and research methods. Students can concentrate in one area or spread their studies across them. In addition to coursework, the department offers research opportunities for interested and qualified students. Participating in research helps students to extend their mastery of decision science, discover whether a research career is right for them, and get to know faculty and graduate students better.

Prerequisites

All Decision Science majors must complete mathematics, statistics, and analytic methods prerequisites (see below), by the end of the sophomore year.

| | |
|--|-------|
| Mathematics Prerequisite | Units |
| 21-111-21-112 Calculus I-II | 10-20 |
| or 21-120 Differential and Integral Calculus | |

| | |
|----------------------------|-------|
| Statistics Prerequisite | Units |
| 36-200 Reasoning with Data | 9 |

Students must take one course from the following set (or an approved alternative). Students may not count a course used to fulfill the Mathematics Prerequisite as also filling the Analytic Methods Prerequisite. Students may not count a course used to fulfill the Analytic Methods Prerequisite as also filling a Decision Science elective.

| | |
|---|-------|
| Analytic Methods Prerequisite | Units |
| 21-122 Integration and Approximation | 10 |
| 21-256 Multivariate Analysis | 9 |
| 21-257 Models and Methods for Optimization | 9 |
| 36-309 Experimental Design for Behavioral & Social Sciences | 9 |
| 36-401 Modern Regression | 9 |
| 36-410 Introduction to Probability Modeling | 9 |
| 80-210 Logic and Proofs | 9 |
| 80-211 Logic and Mathematical Inquiry | 9 |
| 80-315 Modal Logic | 9 |
| 88-252 Cause and Effect | 9 |
| 88-300 Programming and Data Analysis for Social Scientists | 9 |

Curriculum

The core curriculum in Decision Science consists of five courses providing the theoretical perspectives of Decision Science, two courses in research methods, and one capstone.

| | |
|--|-----------|
| Theoretical Perspectives | Units |
| 73-102 Principles of Microeconomics | 9 |
| 85-102 Introduction to Psychology | 9 |
| 88-120 Reason, Passion and Cognition * | 9 |
| 88-223 Decision Analysis | 12 |
| 88-302 Behavioral Decision Making | 9 |
| | 48 |

* 88-120 should be taken in the freshman or sophomore year.

| | |
|---|-------|
| Statistical Research Methods (one course)* | Units |
| 36-202 Methods for Statistics & Data Science | 9 |
| 36-309 Experimental Design for Behavioral & Social Sciences | 9 |
| 85-309 Statistical Concepts and Methods for Behavioral and Social Science | 9 |

*** Be sure to consult with your Decision Science advisor to discuss which course will best fit your plans and goals.**

| | |
|-----------------------------------|----------|
| SDS Research Methods | Units |
| 88-251 Empirical Research Methods | 9 |
| | 9 |

| | |
|----------------------------------|-------|
| Capstone | Units |
| 88-454 Decision Science Capstone | 9 |

Electives 36 units

Complete at least 36 units of courses from the following categories. The selected courses may be from one category or from any combination. Note that not all elective courses are offered every year.

At least two of these courses (18 units) must be Department of Social and Decision Sciences courses (88-xxx) from the approved list.

| | |
|---|-------|
| 1. Biological and Behavioral Aspects of Decision Making | Units |
| 85-350 Psychology of Prejudice | 9 |
| 85-352 Evolutionary Psychology | 9 |
| 85-363 Attention, Its Development and Disorders | 9 |
| 85-375 Crosscultural Psychology | 9 |
| 85-377 Attitudes and Persuasion | 9 |
| 85-442 Health Psychology | 9 |
| 85-443 Social Factors and Well-Being | 9 |
| 85-444 Relationships | 9 |
| 85-446 Psychology of Gender | 9 |

| | | |
|--------|--|---|
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-312 | Decision Models and Games | 9 |
| 88-342 | The Neuroscience of Decision Making | 9 |
| 88-355 | Social Brains: Neural Bases of Social Perception and Cognition | 9 |
| 88-360 | Behavioral Economics | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-372 | Social and Emotional Brain | 9 |
| 88-380 | Dynamic Decisions | 9 |

2. Managerial and Organization Aspects of Decision Making

| | | |
|-----------|---|----|
| 70-311 | Organizational Behavior | 9 |
| 70-381 | Marketing I | 9 |
| 70-443 | Digital Marketing and Social Media Strategy | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 88-150 | Managing Decisions | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 88-451 | Policy Analysis Senior Project | 12 |
| or 88-452 | Policy Analysis Senior Project | |

3. Philosophical and Ethical Perspectives on Decision Making Units

| | | |
|--------|---|---|
| 70-332 | Business, Society and Ethics | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-305 | Game Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |

4. Economic and Statistical Methods for Decision Science Units

| | | |
|--------|---|---|
| 70-374 | Data Mining & Business Analytics | 9 |
| 70-455 | Data Management Fundamentals | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-347 | Game Theory Applications for Economics and Business | 9 |
| 80-405 | Game Theory | 9 |
| 88-255 | Strategic Decision Making | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |
| 88-360 | Behavioral Economics | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-379 | Data-Driven Decision Analysis | 9 |

5. Decision Science and Public Policy

| | | |
|-----------|---|----|
| 84-369 | Decision Science for International Relations | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-261 | Health Policy | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-405 | Risk Perception and Communication | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 88-451 | Policy Analysis Senior Project | 12 |
| or 88-452 | Policy Analysis Senior Project | |

6. Research Methods for Decision Science Units

| | | |
|--------|------------------------------|---|
| 36-303 | Sampling, Survey and Society | 9 |
|--------|------------------------------|---|

| | | |
|--------|--|---|
| 70-460 | Mathematical Models for Consulting | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |

Note: Some courses have additional prerequisites.

Decision Science, B.S. Sample Curriculum

| First-Year | | Second-Year | |
|--|--|-----------------------------------|--|
| Fall | Spring | Fall | Spring |
| 88-120 Reason, Passion and Cognition * | 36-202 Methods for Statistics & Data Science | 85-102 Introduction to Psychology | 88-302 Behavioral Decision Making |
| 36-200 Reasoning with Data | Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | 88-251 Empirical Research Methods | 88-252 Cause and Effect 88-300, or other Analytic Methods course |
| 21-120 Differential and Integral Calculus (or 21-111, depending on placement) | Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | Decision Science Elective | Decision Science Elective |
| Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | Gen Ed or Elective | Gen Ed or Elective | Gen Ed or Elective |
| 73-102 Principles of Microeconomics | Gen Ed or Elective | Gen Ed or Elective | Gen Ed or Elective |

| Third-Year | | Fourth-Year | |
|---------------------------|---------------------------|----------------------------------|----------------------------------|
| Fall | Spring | Fall | Spring |
| Decision Science Elective | 88-223 Decision Analysis | Senior Honors Thesis or Elective | Senior Honors Thesis or Elective |
| Gen Ed or Elective | Decision Science Elective | Decision Science Elective | Elective |
| Elective | Gen Ed or Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |
| Elective | Elective | Elective | Elective |

* 88-120 should be taken as the first course in the Decision Science sequence. It is intended for students in their first or second year; it is offered in Fall and Spring semesters. It may be taken as late as the junior year.

This is presented as a recommended plan for completing major requirements. The major can be completed in as few as two years (not that it must be), but students may not have time for other opportunities such as additional majors or study abroad. Students may declare their major as early as the third week of the spring semester in the freshman year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early - and often - with the Decision Science Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses will be considered as fulfilling requirements of electives in the major. Please send the course syllabus, along with a note explaining how the course addresses fundamental aspects of decision science in one of the six elective categories.

Additional Major in Decision Science

Students who elect Decision Science as an additional major must fulfill all of the requirements of the Decision Science major.

Students pursuing Behavioral Economics with an additional major in Decision Science may only count 36-202, 73-102, 88-120, 88-251 and 88-302 toward the completion of both majors.

Students pursuing Policy and Management with an additional major in Decision Science and may only count 36-202, 73-102, 88-223, and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Decision Science should see the Academic Advisor of the Decision Science program.

The Major in Policy and Management

Christina Fong, Faculty Director

Location: Porter Hall 2231
P-and-M-advisor@andrew.cmu.edu

Connie Angermeier, *Senior Academic Program Manager and Advisor*
Location: Porter Hall 208H
cla2@andrew.cmu.edu
Schedule an appointment: <https://go.oncehub.com/ConnieAngermeier>
(<https://go.oncehub.com/ConnieAngermeier/>)

The Policy and Management major prepares students for key decision-making and management roles in government, non-profit organizations, and business. The major emphasizes analytical approaches to decision making, practical management skills, and empirical techniques necessary for graduates to excel in the public and private sectors. The multidisciplinary curriculum merges frontier knowledge on the ideals of decision making, policy, and data analysis, as well as the realities of individual behavior within various institutional settings that must be confronted if high-quality outcomes are to be attained.

The major is comprised of three required core areas taken by all Policy and Management majors, a capstone course, plus one of four concentration areas to be chosen by the student.

The three core areas are as follows:

The *Policy Core* gives students applied economic training and policy analysis experience. Students will gain an analytical understanding of some of the biggest domestic and global economic policy challenges, and gain an appreciation of the economic analysis of complex decisions, as well as the trade-off between economic and political-based decision making.

The *Management Core* focuses on real-world applications of decision making. Students will develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. The courses provide systematic methods for dealing with the complexities that make decisions difficult, ranging from incorporating issues of risk and uncertainty in decision making to dealing with choices that have mutually conflicting objectives. For example, a business or government agency may need to decide on a policy for mitigating the uncertain impacts of air pollution while simultaneously trying to minimize the costs of such a policy on manufacturing. A firm might want to consider the uncertain reductions in security dangers from alternative policies to protect against terrorism.

The *Empirical Core* focuses on key methods for collecting and analyzing data that are needed to make informed decisions. Students learn to use interviews, surveys, experiments, and econometric methods to enhance their ability to test existing, and design new, policies. Students will create statistical models to address questions asked in conceptual, computational, and data-driven investigations.

The required *Capstone* course gives students hands-on experience in a policy-related area. Students work in teams to apply the research and analytical methods learned in their other courses to a real-world problem.

Finally, the *four concentration areas* consist of four courses chosen by the student, in coordination with the Academic Advisor. The concentrations emphasize different aspects of decision making within the major: (1) Analytics, (2) Policy, (3) Management, and (4) Law. Each of the concentration areas draws upon the research and teaching strength of the Department of Social and Decision Sciences. Additionally, select courses from other areas in the University have been identified and approved as fulfilling elective requirements within the concentrations. More detail will be found in the concentration areas below.

The Policy and Management major provides an excellent combination of theoretical and practical skills for students who intend to seek managerial positions. Because of its strong analytic orientation, it is also an excellent major for those who intend to go on to professional school programs in law, business, or public policy. It is also an appropriate choice for students pursuing graduate degrees in economics, political science, or decision science. One such graduate option is the accelerated master's program offered by the H. J. Heinz III School of Public Policy and Management, in which a student earns both a B.S. in Policy and Management and a M.S. in Public Policy and Management in five years.

Prerequisites

All Policy and Management majors must complete mathematics and statistics prerequisites (see below), by the end of the sophomore year.

| | |
|--|-------|
| Mathematics Prerequisite | Units |
| 21-111-21-112 Calculus I-II | 10-20 |
| or 21-120 Differential and Integral Calculus | |

| | |
|----------------------------|-------|
| Statistics Prerequisite | Units |
| 36-200 Reasoning with Data | 9 |

Curriculum

| | |
|--|-----------|
| Policy Core | Units |
| 73-102 Principles of Microeconomics | 9 |
| 88-221 Markets, Democracy, and Public Policy | 9 |
| | 18 |

| | |
|--|-----------|
| Management Core | Units |
| 88-150 Managing Decisions | 9 |
| or 88-255 Strategic Decision Making | |
| 88-223 Decision Analysis | 12 |
| 88-418 Negotiation: Strategies and Behavioral Insights | 9 |
| or 88-419 International Negotiation | |
| | 30 |

| | |
|---|-----------|
| Empirical Core | Units |
| 36-202 Methods for Statistics & Data Science | 9 |
| 88-251 Empirical Research Methods | 9 |
| 88-252 Cause and Effect | 9 |
| or 88-275 Bubbles: Data Science for Human Minds | |
| | 27 |

| | |
|--|-------|
| Capstone | Units |
| 88-451 Policy Analysis Senior Project | 12 |
| or 88-452 Policy Analysis Senior Project | |

Concentration 36 units

Complete at least 36 units (a minimum of four courses) from the following concentrations of courses. Students are required to declare a concentration before their graduating semester, but are not required to choose a concentration when they initially declare (typically in the freshman or sophomore year). In fact, students are encouraged to take many of the core classes before making their concentration selection so that they can make a well-informed decision.

| | |
|---|-----------|
| 1. Analytics Concentration (minimum four total courses) | Units |
| Programming (one course) | 9 |
| 88-300 Programming and Data Analysis for Social Scientists | 9 |
| Analytics/Empirical electives (select any two courses) | 18 |
| 88-252 Cause and Effect (if not taken in Empirical Core) | 9 |
| 88-275 Bubbles: Data Science for Human Minds (if not taken in Empirical Core) | 9 |
| 88-312 Decision Models and Games | 9 |
| 88-379 Data-Driven Decision Analysis | 9 |
| 88-388 Psychological Models of Decision Making | 9 |
| 36-303 Sampling, Survey and Society | 9 |
| 36-315 Statistical Graphics and Visualization | 9 |
| 70-257 Optimization for Business | 9 |
| 70-374 Data Mining & Business Analytics | 9 |
| 70-455 Data Management Fundamentals | 9 |
| 70-460 Mathematical Models for Consulting | 9 |
| 80-321 Causation, Law, and Social Policy | 9 |
| 90-834 Health Care Geographical Information Systems * | 12 |
| Analytics concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx) | 9 |

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration.

| | |
|---|-----------|
| 2. Policy Concentration (minimum four total courses) | Units |
| Policy electives (select three courses; at least one of the three must be 88xxx) | 27 |
| 88-230 Human Intelligence and Human Stupidity | 9 |
| 88-261 Health Policy | 9 |
| 88-323 Policy in a Global Economy | 9 |
| 88-344 Systems Analysis: Environmental Policy | 9 |
| 88-365 Behavioral Economics and Public Policy | 9 |

| | | |
|--------|---|----|
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-411 | Rise of the Asian Economies | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 36-303 | Sampling, Survey and Society | 9 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-421 | Emerging Energy Policies | 9 |
| 19-639 | Policies of the Internet | 12 |
| 73-328 | Health Economics | 12 |
| 80-244 | Environmental Ethics | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 84-310 | International Political Economy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 90-798 | Systems Analysis: Environmental Policy* | 12 |

Policy concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx) 9

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

3. Management Concentration (minimum four total courses) Units

Management electives (select three courses; at least one of the three must be 88xxx) 27

| | | |
|--------|---|---|
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-341 | Team Dynamics and Leadership | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-411 | Rise of the Asian Economies | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights (if not taken in Management Core) | 9 |
| 88-419 | International Negotiation (if not taken in Management Core) | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-430 | International Management | 9 |

Management concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx) 9

4. Law Concentration (minimum four total courses) Units

Topics of Law (select one course) 9

| | | |
|--------|-----------------------------------|---|
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

Law electives (select any two courses) 18

| | | |
|--------|--|---|
| 88-281 | Topics in Law: 1st Amendment (if not used in required) | 9 |
| 88-284 | Topics of Law: The Bill of Rights (if not used in required) | 9 |
| 70-364 | Business Law | 6 |
| 70-365 | International Trade and International Law | 9 |
| 73-408 | Law and Economics | 9 |
| 76-219 | Law & Blame | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-447 | Global Justice | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |

Law concentration breadth elective (select one course from any of the other three concentrations; must be 88xxx) 9

NOTE: Some courses have additional prerequisites.

Policy and Management, B.S. Sample Curriculum

| First-Year | | Second-Year | |
|--|--|---|--|
| Fall | Spring | Fall | Spring |
| 88-150 Managing Decisions | 36-202 Methods for Statistics & Data Science | 88-251 Empirical Research Methods | 88-221 Markets, Democracy, and Public Policy |
| 36-200 Reasoning with Data | 73-102 Principles of Microeconomics | 88-275 Bubbles: Data Science for Human Minds | 88-223 Decision Analysis |
| 21-120 Differential and Integral Calculus (or 21-111, depending on placement) | Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | 88-418 Negotiation: Strategies and Behavioral Insights or 88-419 International Negotiations | 88-252 Cause and Effect |
| Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | Pick One (Grand Challenge Seminar, FYW, Disciplinary Perspectives: Humanities) | Gen Ed or Elective | Gen Ed or Elective |
| Gen Ed or Elective | Gen Ed or Elective | Gen Ed or Elective | Gen Ed or Elective |

| Third-Year | | Fourth-Year | |
|--|--|--|--|
| Fall | Spring | Fall | Spring |
| Policy & Management concentration elective | Policy & Management concentration elective | Capstone (either 88-452 in fall or 88-451 in spring) | Capstone (either 88-451 in spring or 88-452 in fall) |
| Policy & Management concentration elective | Policy & Management concentration elective | Senior Honors Thesis or Elective | Senior Honors Thesis or Elective |
| Gen Ed | Elective | Complete remaining gen eds/electives | Complete remaining gen eds/electives |
| Elective | Elective | additional Policy & Management concentration electives | additional Policy & Management concentration electives |
| Elective | Elective | additional Policy & Management concentration electives | additional Policy & Management concentration electives |
| Students may consider the CMU Washington Semester Program or study abroad in this semester | Students may consider the CMU Washington Semester Program or study abroad in this semester | | |

This is presented as a recommended plan for completing major requirements. Students may declare their major as early as the third week of the spring semester in the freshman year. Students who are planning to attend the Washington Semester Program, to study abroad, to apply for the Heinz Accelerated Masters Program, or to pursue an additional major/minor may have a very different curriculum map and should consult early – and often – with the Policy and Management Academic Advisor.

Students are encouraged to consider the Washington Semester Program as part of their education. Suitable courses may be considered as fulfilling requirements of concentration electives in the major. Please discuss course selections with the Academic Advisor during the application phase to the program.

Additional Major

Students who elect Policy and Management as an additional major must fulfill all of the requirements of the Policy and Management major. For additional majors in Policy and Management, courses taken as concentration electives may not count toward the student's primary major or other program.

Students pursuing Behavioral Economics, Policy, and Organizations with an additional major in Policy and Management may only count 36-202, 73-102, and 88-251 (and 88-252, if taken in Empirical Core) toward the completion of both majors.

Students pursuing Decision Science with an additional major in Policy and Management may only count 36-202, 73-102, 88-223, and 88-251 toward the completion of both majors.

Additional majors cannot count menu electives toward simultaneously fulfilling more than one major or minor. Students who are interested in an additional major in Policy and Management should see the Academic Advisor of the Policy and Management program.

The Minor in Behavioral Economics

Peter Schwardmann, *Faculty Director*

Location: Porter Hall 223J

schwardmann (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/>)

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 schwardmann@cmu.edu)@andrew.cmu.edu ([http://
 coursecatalog.web.cmu.edu/schools-colleges/
 dietrichcollegeofhumanitiesandsocialsciences/
 departmentofsocialanddecisionsciences/schwardmann@cmu.edu\)](http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/))

Lizzy Stoyle, *Senior Academic Advisor*

Location: 208G

estoyle@andrew.cmu.edu

Schedule an appointment: <https://go.oncehub.com/LizzyStoyle> ([https://
 go.oncehub.com/LizzyStoyle/](https://go.oncehub.com/LizzyStoyle/))

The minor in Behavioral Economics, provides students with a selective survey of disciplinary perspectives. The field of Behavioral Economics (BE) integrates perspectives from Economics and Psychology to better understand how people make consequential decisions and to leverage this understanding to improve the design of the policies, programs, and institutions that govern such behavior. The core requirements include courses in Economics, Psychology, Behavioral Economics, and quantitative methods- including experimental design and econometrics. Students who elect Behavioral Economics as a minor must complete the six core courses and one elective from the elective set (below).

Students may double-count one course with another major or minor. 73-102 is excluded from this double count policy.

Curriculum

The core curriculum in Behavioral Economics consists of one quantitative course, two Economic courses, one Psychology course, and two Behavioral Economics courses.

CURRICULUM 63

Core Courses 54

| | | |
|-------------------------------|---|-----------|
| Quantitative Methods Core | | Units |
| 36-202 | Methods for Statistics & Data Science | 9 |
| Economics Core | | Units |
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| Second-Level Economics Course | | |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| or 73-103 | Principles of Macroeconomics | |
| or 73-158 | Markets, Models, and Math | |
| or 73-230 | Intermediate Microeconomics | |
| or 73-328 | Health Economics | |
| or 73-347 | Game Theory Applications for Economics and Business | |
| or 73-359 | Benefit-Cost Analysis | |
| or 73-408 | Law and Economics | |
| or 73-421 | Emerging Markets | |
| or 73-427 | Sustainability, Energy, and Environmental Economics | |
| | | 18 |
| Psychology Core | | Units |
| 88-120 | Reason, Passion and Cognition | 9 |
| Behavioral Economics Core | | Units |
| 88-360 | Behavioral Economics | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| or 88-365 | Behavioral Economics and Public Policy | |
| | | 18 |

* Behavioral Economics core courses CANNOT double count with the elective course.

Elective Courses 9

Complete at least one of the courses (9 units) from the following list. Note: Behavioral Economics core courses CANNOT double count with the elective course.

| Elective Courses | Units | |
|------------------|---|---|
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-251 | Empirical Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |
| 88-255 | Strategic Decision Making | 9 |
| 88-261 | Health Policy | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |
| 88-302 | Behavioral Decision Making | 9 |
| 88-312 | Decision Models and Games | 9 |
| 88-323 | Policy in a Global Economy | 9 |
| 88-342 | The Neuroscience of Decision Making | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-372 | Social and Emotional Brain | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-435 | Decision Science and Policy | 9 |

Note: Some courses have additional prerequisites.

The Minor in Decision Science

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Connie Angermeier, *Senior Academic Program Manager*
Advises Additional Majors and Minors in Decision Science
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(<https://go.oncehub.com/ConnieAngermeier/>)

The minor in Decision Science provides students with a selective survey of disciplinary perspectives. The courses present descriptive and normative approaches to judgment and decision making, as well as some application of theories and results to real-world problems. Students who elect Decision Science as a minor must complete the four core courses (below) and two electives from the elective set (below).

Students may double-count two courses with another major or minor.

Curriculum

57 units

Core Courses

39 units

| | | |
|--------|-------------------------------|----|
| 73-102 | Principles of Microeconomics | 9 |
| 88-120 | Reason, Passion and Cognition | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |

Elective Courses

18 units

Complete two courses from the following categories. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx).

| | | |
|---|--|-------|
| 1. Biological and Behavioral Aspects of Decision Making | | Units |
| 85-443 | Social Factors and Well-Being | 9 |
| 85-350 | Psychology of Prejudice | 9 |
| 85-352 | Evolutionary Psychology | 9 |
| 85-363 | Attention, Its Development and Disorders | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-377 | Attitudes and Persuasion | 9 |
| 85-442 | Health Psychology | 9 |
| 85-444 | Relationships | 9 |
| 85-446 | Psychology of Gender | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-312 | Decision Models and Games | 9 |
| 88-342 | The Neuroscience of Decision Making | 9 |
| 88-355 | Social Brains: Neural Bases of Social Perception and Cognition | 9 |
| 88-360 | Behavioral Economics | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-372 | Social and Emotional Brain | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 2. Managerial and Organizational Aspects of Decision Making | | Units |
| 70-311 | Organizational Behavior | 9 |
| 70-381 | Marketing I | 9 |
| 70-443 | Digital Marketing and Social Media Strategy | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 88-150 | Managing Decisions | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 88-451 | Policy Analysis Senior Project | 12 |
| or 88-452 | Policy Analysis Senior Project | |

| | | |
|--|---|-------|
| 3. Philosophical and Ethical Perspectives on Decision Making | | Units |
| 70-332 | Business, Society and Ethics | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-305 | Game Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 4. Economic and Statistical Methods for Decision Science | | Units |
| 70-374 | Data Mining & Business Analytics | 9 |
| 70-455 | Data Management Fundamentals | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-347 | Game Theory Applications for Economics and Business | 9 |
| 80-405 | Game Theory | 9 |
| 88-255 | Strategic Decision Making | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |
| 88-360 | Behavioral Economics | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-379 | Data-Driven Decision Analysis | 9 |
| 5. Decision Science and Public Policy | | Units |
| 84-369 | Decision Science for International Relations | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-261 | Health Policy | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-405 | Risk Perception and Communication | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 88-451 | Policy Analysis Senior Project | 12 |
| or 88-452 | Policy Analysis Senior Project | |
| 6. Research Methods for Decision Science | | Units |
| 36-303 | Sampling, Survey and Society | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |

Note: Some courses have additional prerequisites.

The Minor in Policy and Management

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Regardless of major, many Carnegie Mellon graduates will face analytical and managerial challenges and responsibilities in their professional lives. Whether these are in their area of expertise or in more general settings, these roles will to some degree require assumption of the responsibility for directing the work of others. The Policy and Management minor is intended for students who expect to need these management concepts and skills.

Students may double-count one course with another major or minor.

Curriculum**57 units**

Required Courses 39 units

| | | |
|--------|---------------------------------------|----|
| 73-102 | Principles of Microeconomics | 9 |
| 88-150 | Managing Decisions | 9 |
| | or 88-255 Strategic Decision Making | |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-223 | Decision Analysis | 12 |

18 units Electives

Complete two courses (at least 18 units) from any of the concentrations (Analytics, Policy, Management, and Law). **Courses do not need to be taken from the same concentration.** The courses are listed by their concentration categories as a way to guide students. At least one of the courses (9 units) must be a Social and Decision Sciences course (88-xxx).

Analytics Concentration

| | | |
|--------|---|----|
| 88-252 | Cause and Effect | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |
| 88-312 | Decision Models and Games | 9 |
| 88-379 | Data-Driven Decision Analysis | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |
| 21-257 | Models and Methods for Optimization | 9 |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 70-374 | Data Mining & Business Analytics | 9 |
| 70-455 | Data Management Fundamentals | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 90-834 | Health Care Geographical Information Systems * | 12 |

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Policy Concentration

| | | |
|--------|---|----|
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-261 | Health Policy | 9 |
| 88-323 | Policy in a Global Economy | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-411 | Rise of the Asian Economies | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 36-303 | Sampling, Survey and Society | 9 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-421 | Emerging Energy Policies | 9 |
| 19-639 | Policies of the Internet | 12 |
| 73-328 | Health Economics | 12 |
| 80-244 | Environmental Ethics | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 84-310 | International Political Economy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 90-798 | Systems Analysis: Environmental Policy * | 12 |

* other Heinz courses are also approved. Please talk with the P&M advisor for information about getting approval for Heinz course registration

Management Concentration

| | | |
|--------|---|---|
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-341 | Team Dynamics and Leadership | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-411 | Rise of the Asian Economies | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 70-311 | Organizational Behavior | 9 |

| | | |
|--------|------------------------------|---|
| 70-332 | Business, Society and Ethics | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-430 | International Management | 9 |

Law Concentration

| | | |
|--------|--|-------|
| | | Units |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |
| 70-364 | Business Law | 6 |
| 70-365 | International Trade and International Law | 9 |
| 73-408 | Law and Economics | 9 |
| 76-219 | Law & Blame | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-447 | Global Justice | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |

Faculty

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Department of Social and Decision Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

88-120 Reason, Passion and Cognition

Fall: 9 units

How do we make decisions? Reason, Passion, and Cognition will be an introduction to the psychology of preference, judgment, and choice. Why do people behave in ways that cannot be defended as "rational" - and how do these deviations inform us about the processes that the mind uses to make fast-and-frugal decisions? The course will focus on the ways that cognitive and emotional processes relate to decisions made in the laboratory and in everyday decision making and will be based on rigorous experimental research.

88-150 Managing Decisions

Fall: 9 units

We make decisions constantly, but making good decisions is hard. Future employers will pay handsomely for decisions that are well thought out, defensible, and understandable. How do we decide how to decide? What is a "good" decision? This course will introduce normative decision-making concepts, including how to formulate decision problems and techniques that account for uncertainty and time preference. Students will learn how to place a quantitative value on information. The course will introduce key decision-making concepts using applications from fields such as decision sciences, business and economics, and public policy. Although prior knowledge of Microsoft Excel spreadsheets is not required, prior familiarity with Excel and a general level of numeracy will be useful.

88-198 Research Training: Social and Decision Sciences

Fall and Spring

This course is part of a set of 100-level courses offered by Dietrich departments as independent studies for second-semester freshmen, and first- or second-semester sophomores, in the College. In general, these courses are designed to give students some real research experience through work on a faculty project or lab in ways that might stimulate and nurture subsequent interest in research participation. Faculty and students devise a regular meeting and task schedule. Each Research Training course is worth 9 units, which generally means a minimum of about 9 work-hours per week. These courses are offered only as electives; i.e., they cannot be applied toward a college or major requirement, although the units do count toward graduation as elective units. Additional details (including a roster and descriptions of Research Training Courses available in any given semester) are available in the Dietrich Academic Advisory Center.

88-200 SDS Colloquium

Spring: 3 units

The SDS Colloquium is an opportunity for students to gather and discuss topics related to the various opportunities available both during the undergraduate career and after graduation. Students will explore areas such as academic planning, personal and professional values, and professional communication/communication skills. Co-curricular experiences such as: study abroad, research, internship/career planning and goal setting, and graduate school are among the topics to be presented. Students will have the opportunity to talk with SDS advisors, faculty, and alumni as well as with other professionals from around the University. Sophomore or junior standing is required.

88-221 Markets, Democracy, and Public Policy

Spring: 9 units

In this course, students will achieve an analytical understanding of some of the most pressing policy challenges of our day. The focus of the course lies in the interaction between markets and government. The course will first introduce analytical foundations of how markets, voting and governments work, and important shortcomings of each. The course will briefly touch on a comparative cross-national perspective on the balance between markets and government pursued in different countries. The second part of the course focuses on a substantive understanding of current policy issues, including health care, inequality, economic conditions of the politically pivotal middle class, resource constraints, globalization, technological change, and the role of all of these topics in political debates, and voter demands.

Prerequisite: 73-102

88-223 Decision Analysis

Spring: 12 units

This course offers practical guidance about how to make better decisions and teaches students how to use modeling to do decision analysis. We analyze decisions involving uncertainty, risk, and time delay. In addition to methods of decision analysis, the course will also emphasize sensitivity analysis and communication of recommendations.

Prerequisites: 36-247 or 36-217 or 36-200 or 36-207 or 36-211 or 70-207 or 36-200 or 36-225 or 36-201

88-230 Human Intelligence and Human Stupidity

Fall: 9 units

By some standards, humans are an incredibly intelligent species. We have set foot on the moon, split the atom, and produced extraordinary works of art and literature (including the complete works of Shakespeare, which, despite theoretical accounts to the contrary, no amount of monkeys on typewriters has ever been able to duplicate). And yet, we are also the species that has brought about the Darwin Awards, spent \$125 million sending a probe to Mars which was unable to function because engineers failed to convert inches to centimeters, and produced cringe-worthy works of art and literature (including the 1964 movie "Santa Claus Conquers the Martians" which no amount of monkeys on typewriters would ever want to duplicate.). What is intelligence and how does it vary across individuals and over our lifespans? What are we good at, and what are we bad at, and why? Are there things that that make us dumber? Are there things we can do to make ourselves smarter? How should what we know about the range of human intellectual abilities guide policy, education, law, medicine, and business; what implications does this have regarding the tasks/jobs that humans should be doing and the tasks/jobs that machines ought to do? Using cutting edge research from psychology and decision science, this course will explore the strange contradiction that defines the human experience: How are we simultaneously so smart and so dumb?

88-231 Thinking in Person vs. Thinking Online

Intermittent: 9 units

Being online changes how we think. Different media lead us to ask different questions, remember (or forget) different information, attend to different details, and interact with other people in different ways. These types of thinking aren't inherently better or worse, but they may be better or worse for facilitating specific goals. Too often, we use a particular medium/technology without considering how it will influence our thinking. This can lead us to be less efficient or less effective at a task than we otherwise might be, or can qualitatively change the nature of our outcomes. In this class, we will explore how the media we use affects the character of our thinking, so as to enable students to make mindful and deliberate choices about how to interact with media in ways that support the type of thinking desired and appropriate for their goals. Moreover, we will examine how to optimize media for specific goals in important applied domains, such as education, medicine, policy, child-rearing, and dating.

88-251 Empirical Research Methods

Fall: 9 units

This course teaches students how to evaluate and conduct original research regarding human behavior, whether it be in economic, social, or political settings. The course gives students practical experience in many of the most commonly used research techniques, including surveys, experiments, and quasi-experimental analysis. Although the course focuses primarily on the relationship between formulating research questions and implementing the appropriate methods to answer them, students can expect regularly to apply the statistical techniques learned in the course prerequisites, including regression.

Prerequisites: 36-247 or 36-207 or 36-201 or 36-200

88-252 Cause and Effect

Spring: 9 units

Causal questions are pervasive in the social and behavioral sciences, and empirical researchers often use regression analysis as a tool for tackling such questions. This course focuses on the scientific problem of analyzing causal hypotheses in real-world settings, not on the mathematical details of regression. After clearly distinguishing prediction from causation, we discuss how to represent causal hypotheses and how to use regressions to analyze both predictive and causal hypotheses. Using in-class data exercises throughout, we will examine how to move from an interesting but somewhat vague question about the world (e.g., do police discriminate based on race and gender, do NFL athletes choke under high pressure, does parenthood improve happiness) to a clear statistical model that, when estimated, meaningfully addresses the question asked. The course emphasizes causal analysis as the main research goal and multivariate linear regression as the main statistical tool. After mastering basic techniques, we will introduce students to more advanced econometric approaches such as panel regressions and instrumental variables to deal with trickier settings in which causal inference is more challenging (e.g., do more guns lead to more violence?). In keeping with the hands-on philosophy of the course, a central focus of the semester will be a group research paper/presentation where students will have the opportunity to formulate and empirically test a research question of their choosing. Students will learn how to find, clean, and analyze a new dataset, and then concisely communicate their findings in the form of a scientific paper (and accompanying presentation). The research project makes this course excellent preparation for any student who hopes to ultimately write an undergraduate thesis.

Prerequisites: 36-202 or 85-309 or 70-208 or 36-309

88-255 Strategic Decision Making

Fall: 9 units

How do people navigate social interactions when their goals are in conflict? When should a person cooperate and when should a person pursue self-interest in an ongoing social interaction? How can a business establish strategic partnerships that create value and at the same time battle with competitors to take advantage of the value they create? Strategic decision making requires a framework to think through the implications of cooperation and of competition. This course gives you a systematic approach to understanding how people, firms, or countries interact with one another to achieve their own goals. We focus on the practical application of theory-based strategic principles and on their behavioral validity (whereas traditional game theory courses usually focus on formal modeling techniques). Readings will focus on real-life stories accompanied by a full analysis of the principles involved. The class will be organized as a seminar, centered around discussion, not lecture. Students will also be placed in the role of strategist in occasional simulations in class.

88-261 Health Policy

Fall: 9 units

This course is a deep dive into the US healthcare industry, the economy's biggest sector. You will 1) learn about the most pressing contemporary health and healthcare issues faced by American society; 2) understand the structure of the US healthcare system and the decision-making of its main stakeholders (patients, physicians, hospitals, insurers, governments, and policymakers); and 3) deploy the tools from modern behavioral science and economics to think through policies that improve health and social welfare.

88-275 Bubbles: Data Science for Human Minds

Fall: 9 units

Open discussions turn into echo chambers; optimistic traders pump good money into bad stocks; we fail to see, or sympathize, beyond the limits our culture, upbringing, or education prescribe. These bubbles and #8212; information bubbles, market bubbles, social bubbles and #8212; drive us to ask some of the most basic questions in the social sciences: Why do we believe the things we do? Where do our ideas come from, and how can we measure the consequences of their conjecture, spread, and evolution? How can we design systems to make us better thinkers? In this introduction to the "big data" study of human behavior, we'll learn some key concepts and simple computational tools for studying how people gain and share information, with a focus on what they say and write. And we'll apply these tools to social behaviors from the writing of Harry Potter fan fiction to online trolling, to science, markets, and liberal democracy itself. The class will include conceptual, computational, and data-driven investigations; students in social science, humanities, engineering and the sciences are equally welcome. At the end of this course, students will be able to build models for how people think and talk to each other, to see how thinking and talking work in both the past and present, and to imagine, and even design, systems that might help us think, and talk, together more effectively in the future. Pre-requisites: willingness and initiative to work with real-world data. Prerequisites: 36-200 or 70-207

88-281 Topics in Law: 1st Amendment

Fall: 9 units

In their firm desire to perfect the new Constitution, which defined and limited the powers and roles of their new government, the founding fathers insisted on explicit statements that would protect the rights of the new nation's citizens. Indeed, the protection of these essential rights in many ways drove and defined their successful rebellion from Britain. This impulse resulted in ten amendments to the Constitution, which we have come to know as the Bill of Rights. The very first (and arguably considered at the time as the most essential) of these was the First Amendment, which we sometimes call the "free speech" amendment to the Constitution. This amendment guarantees every U.S. citizen five freedoms: freedom of religion, speech, press, peaceable assembly, and the freedom to petition the government for redress of grievances. This course examines the historical and philosophical roots of this key constitutional amendment, how it has been fleshed out and defined over time through case law, and the bases of some more recent critics of this amendments and current interpretations.

88-284 Topics of Law: The Bill of Rights

Spring: 9 units

This course examines the history and place of the Bill of Rights in our nation's constitutional framework. It focuses on the historical origins of the U.S. Constitution, of each of the first ten amendments to the Constitution (that we refer to as the "Bill of Rights"), how the meanings and interpretations of these have evolved over time, and what they mean to us today. Each article of the Bill of Rights will be examined in terms of its original intentions, and then through cases that have challenged and been interpreted through the Bill's articles.

88-300 Programming and Data Analysis for Social Scientists

Spring: 9 units

This course presents an introduction to computational thinking through practice with data analysis. Students will develop extensive expertise using the statistical programming language R. Designed primarily with social science majors in mind, students will use a variety of data structures to represent information and solve problems. The course is conducted in a "flipped classroom" style, and places a heavy emphasis on hands-on programming and #8212; in every class, students will practice writing computer programs to conduct analysis and explore social science phenomena. Students will develop skills in all facets of the data analysis pipeline, from installing and loading packages to reading-in files to data cleaning, munging, visualization and modeling. The course is primarily intended for students who have limited familiarity with coding, and assumes no previous exposure to R.

Prerequisites: 36-200 or 36-201

88-302 Behavioral Decision Making

Fall and Spring: 9 units

Behavioral decision making is the study of how people make decisions, in terms that can eventually help them to make better decisions. It draws together research from psychology, economics, political science, and management, among other fields. It has applications that range from managing potentially hazardous technologies, to involving patients more fully in the choice of medical procedures, to the design of computer-interactive systems. The course covers behavioral theories of probabilistic inference, intuitive prediction, preference, and decision making. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, strategies for combining information from different sources and dealing with conflicting objectives, and the roles of group and emotional processes in decision making. The course emphasizes the mutually reinforcing relationship between theory and application.

Prerequisites: (36-225 or 36-217 or 36-247 or 36-200 or 36-220 or 70-207 or 36-211 or 36-207 or 36-201) and 88-120

88-312 Decision Models and Games

Spring: 9 units

Humans often make decisions in changing and uncertain situations. A car driver entering a new city must adjust decisions rapidly while moving along heavy traffic; firefighter crews entering a burning building must maintain awareness of the development of fire; citizens in a country must change their activities based on the evolution of a pandemic and the restrictions imposed. While challenging, humans are an adaptable species. We plan and re-adjust our plans to changing conditions; we keep aware of potentially new courses of action; and we manage our limited time, information, and attention to changing environments. How do humans make decisions in dynamic situations? This course will explore human decision making as a dynamic process resulting from human interactions with the environment. The course uses decision games to illustrate how humans learn and adapt to changing conditions of choice, and computational models to simulate decision processes and environmental dynamics. Decision Models and Games will provide: (1) foundational perspectives for using models to represent the dynamics of environments and human decision processes; (2) tools to build computational models of human decision making and of dynamic environments; and (3) practical illustrations of how models and games can be used to understand and generate solutions to a wide range of decision problems, from simple choices to large scale consequential decisions.

Prerequisites: 36-201 or 70-207 or 36-200

88-323 Policy in a Global Economy

Fall: 9 units

From the dawn of the New Deal through the presidency of Barack Obama, the U.S. led the development of an open, global system of relatively free trade and global capital flows. In the current political environment, leaders on both the American political left (like Senator Bernie Sanders) and the political right (like Donald Trump), have called into question this bipartisan consensus in favor of freer trade and investment. That turn away from globalization has been accelerated by the COVID-19 pandemic. Was the earlier pro-globalization consensus wrong? Is globalization good or bad for the U.S. economy? What are the impacts of globalization on the rest of the world? How has economic globalization impacted the environment and income inequality in the U.S. and around the world? How should the Biden Administration seek to manage international economic policy? This course provides future policy makers and managers with the knowledge and analytical tools necessary to understand economic globalization and its effects. These issues will be studied using the analytical tools and concepts of international economics. Guest lectures and case studies will provide a range of perspectives on current policy debates. The course will also examine science-based policies that could maximize the benefits and minimize the disruption generated by globalization. The fall 2021 version of the course will examine the global macroeconomic impact of the COVID-19 pandemic and the ways in which international policy coordination and #8212; or lack thereof and #8212; worsened that impact.

Prerequisite: 73-102

Course Website: https://api.heinz.cmu.edu/courses_api/course_detail/90-860/

88-341 Team Dynamics and Leadership

Fall: 9 units

Much of the work in groups and organizations consists of communication. You communicate to get information that will be the basis of decisions, to provide a vision for the people who work for and with you, to coordinate activity, and to sell yourself and your work. The goal of this course is to identify sources of communication problems within an organization and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. This course is not a practicum in public speaking or writing, although you will get some experience writing, speaking and managing impressions. Rather the intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly do when you return to work. Readings come from both the research and the managerial literatures. Among the topics considered are managerial communication, persuasion and conformity, self presentation and person perception, social networks. Cases and group projects give you an opportunity to apply what you've learned.

Prerequisites: 36-220 or 36-225 or 70-207 or 36-217 or 36-201 or 36-247 or 36-207 or 36-200

88-342 The Neuroscience of Decision Making

Intermittent: 9 units

Because we are human, feelings provide the basis for reason and rational decision-making. Consider for example, that brain-damaged patients left devoid of emotion struggle to make the most elementary decisions: while they are able to layout the pros and cons of a decision, but they are unable to make the final choice. This course will discuss seminal discoveries in affective neuroscience underlying decision-making.

Prerequisites: 88-120 or 85-211

88-344 Systems Analysis: Environmental Policy

Intermittent: 9 units

Systems Analysis: Environmental Policy provides an introduction to how environmental policies have been and can be designed/created, implemented, and evaluated amidst complex information-based, social, political, and cultural processes. The course emphasizes a systems-based methodological approach for addressing the complexities involved in framing, analyzing, and designing an implementation plan for policy construction. The course also explores through landmark and contemporary case studies several dimensions of environmental policy-making: - Contextual, historical, and structural aspects of environmental policy-making at the local, state, federal, and international levels - Use of quantitative and qualitative analytical tools (from core program + new tools) - The process of how policies derive their meanings.

88-355 Social Brains: Neural Bases of Social Perception and Cognition

Intermittent: 9 units

By some accounts, the large expansion of the human brain evolved due to the complex demands of dealing with social others?competing or cooperating with them, deceiving or empathizing with them, understanding or misjudging them. This discussion-based seminar surveys the emerging field of social cognitive neuroscience and its multi-level approach to understanding the brain in its social context. We will review current theories and methods guiding the field and recent research examining the neural bases of social processes, including: theory of mind, empathy, emotion, morality, among others. We will also discuss broader questions that apply to the specific topics that the course covers, including: What are appropriate levels of description for the target phenomena? How can different disciplines in neuroscience and the social sciences contribute to social neuroscience research? What can we learn from animals? behavior about human social cognition? Do neural systems exist that are specialized for social cognition, or do the systems that participate in social cognition have more general cognitive functions?

Prerequisites: 85-355 or 85-310 or 85-340 or 88-251

88-360 Behavioral Economics

Fall: 9 units

This course introduces students to behavioral economics, an emerging subfield of economics that incorporates insights from psychology and other social sciences into economics. We will examine evidence on how human behavior systematically departs from the standard assumptions of economics, and then investigate attempts by behavioral economists to improve economic analyses.

Prerequisites: (21-120 or 21-112) and (73-100 or 88-220 or 73-102)

88-365 Behavioral Economics and Public Policy

Fall: 9 units

Economics has up to now been the social science that has been most broadly and deeply involved in public policy. With its rational choice perspective, the economic perspective has tended to favor certain types of policies namely those that enhance the efficiency of market mechanisms and lower the cost of information. In this course we will spend the first several classes reviewing the assumptions, implications for public policy and limitations of the rational choice perspective. The remainder of the course will then be devoted to examining different public policy issues, including saving, health care, crime and drug abuse, through the competing lenses of traditional and behavioral economics.

Prerequisites: 73-102 or 73-100 or 88-220

88-366 Behavioral Economics of Poverty and Development

Intermittent: 9 units

This course will introduce students to the study of economic development and poverty alleviation, with a special focus on recent insights from the intersection of psychology and economics. We will primarily focus on the health, microfinance, agriculture, and education sectors in developing countries. The course will have a methodological component largely centered on using experiments to evaluate interventions and policies that apply to households, small firms, and farms. While we will cover standard economic approaches, we will give extra attention to how a behavioral lens can help in both understanding development issues (e.g. barriers to household risk management) and in designing effective interventions (e.g. the timing of fertilizer sales).

Prerequisites: (88-220 or 73-100 or 73-102) and 36-202

88-367 Behavioral Economics & Field Experiments in Organizations

Spring: 9 units

Behavioral Economics is a sub-field of economics that, relying on insights from psychology and decision-making, aspires to describe actual behavior with greater empirical accuracy and psychological realism than that implied by the standard neoclassical model. In this course, we will investigate the success of this approach in explaining ostensible anomalies in the "wild" such as under-savings for retirement, over-consumption of unhealthy food, extreme aversion to losses among investors, workers, and home-owners, the over-confidence of corporate CEOs and NFL general managers, and the influence of emotions on domestic violence, stock market activity, and risk-taking. We will first document and review the underlying theory for three conceptual departures from the standard model -non-standard preferences (e.g., present-bias, reference dependence), non-standard beliefs (e.g., overconfidence, gambler's fallacy), and non-standard decision-making (e.g., heuristics, emotions, framing effects)-and then quickly move to assess the evidence for these claims in field settings. We will additionally explore how markets respond to behavioral biases, and discuss recent research in behavioral policy with an emphasis on policies aimed at increasing savings, improving food choice, and heightening program take-up and compliance. The course will be paper-centric and we will review a variety of popular empirical methods from field experiments to quasi-experimental approaches (e.g., estimation through regression-based panel analyses, difference-in-differences, and instrumental variables). Student evaluation will be based on a mix of exams, problem sets, written assignments, and class participation.

Prerequisites: 73-102 and 36-202

88-372 Social and Emotional Brain

Intermittent: 9 units

This course provides an introductory survey of the methods and findings in social and affective neuroscience. Half the course is lecture style and covers the basics of neuroanatomy, neurochemistry, and neuroendocrine systems, as well as a survey of relevant neuroscience methods (neuroimaging, neuropsychological, psychophysiological, transcranial magnetic stimulation, etc.). The other half of the course is more like a seminar, where each week we will discuss a couple seminal empirical papers from the scientific literature. Topics include interpersonal relationships, prosocial behavior, aggression, prejudice, emotion regulation, stress, etc.

Prerequisite: 85-102

88-379 Data-Driven Decision Analysis

Intermittent: 9 units

Business managers and public policymakers who make good decisions are in high demand and are richly rewarded. Increasingly, that decision making must occur in dynamic, data-rich environments. In those environments, having an extensive analytical toolkit is essential for success. Building on the foundations laid by prior coursework, we will cover advanced analytical topics from the decision sciences, such as utility function elicitation, optimal decision making under uncertainty and imperfect information, valuing flexibility with real options, portfolio theory, artificial intelligence (AI) and evolutionary computation methods, robust decision making, and Monte Carlo simulation and variance reduction methods. The focus of this course is normative, rather than descriptive decision making. The course will make extensive use of Microsoft Excel and students are expected to possess a high level of numeracy upon enrollment. Although we will touch on the theoretical foundations of the material, our primary focus will be on getting our hands dirty by using the techniques covered. The material covered in this class will be taught using real-world problems and place a high value on using messy, often-incomplete real-world data where the strengths and weaknesses of various tools can be evaluated. Assignments in the course will be "case" style, and include applications to subjects such as climate change, corporate investment, energy policy, geoengineering, and health policy risks. Students will evaluate various decision problems in each case and present and defend their analyses.

Prerequisites: (36-207 or 36-200 or 70-207 or 36-225) and (19-301 or 19-351 or 70-257 or 88-223)

88-380 Dynamic Decisions

Intermittent: 9 units

Decisions we make every day may range from simple to highly complex. For example, during driving we make many effortless and routine decisions (judging the distance to the front car, the speed, the directions), while other decisions such as allocating limited time over multiple school projects in the presence of overwhelming distractions may be very complex. These and many of the decisions we make over-time are, however, very similar. The way humans make dynamic decisions depend on individualized experience, cognitive abilities, and their interaction with the particular conditions of the decision environment. In this course, students will understand how decisions are made from experience, in different dynamic situations; how our cognitive processes (e.g., attention, memory, risk tendencies, and other factors), and how the characteristics of the environments (e.g., time constraints, workload, dynamic change) influence the way those decisions are made. Students will use simulations of dynamic systems (e.g., microworlds/decision games) to understand how humans learn and adapt to changing conditions of choice. Students will also learn to construct cause-effects causal loop and stock-and-flow diagrams to represent dynamic systems, and to construct actionable models of those systems using VENSIM-PLE. Students will learn the process of analyzing complex dynamic decision making problems by working on a semester-long project. In a particular case of an accident or a disaster (natural or man-made) in a context (e.g., aviation, management, social issues and others) students will analyze the sources of error, construct causal-loop diagrams, stock and flow diagrams and represent their models in VENSIM-PLE to construct scenarios that help analyze the consequences of potential decisions in the case example. Students will learn to interpret simulation results to provide decision recommendations, in a final report.

Prerequisites: (85-102 or 88-120 or 88-230 or 85-211 or 85-213 or 85-241) and (36-200 or 36-201)

88-388 Psychological Models of Decision Making

Intermittent: 9 units

This course provides an introduction to the techniques and theories for modeling decision making. The topics covered include: signal detection theory, normative and descriptive decision modeling, multidimensional scaling, and diffusion models. The course will include an introduction to the theory behind the models as well as "hands on" computational applications of the models with data. The topics covered in this course can be used in a variety of applied settings-ranging from medical and public policy to marketing and psychological research-to produce simplified representations of seemingly complex phenomena.

Prerequisites: (36-200 or 36-201) and (21-112 or 21-120)

88-397 SDS Undergraduate Research - mini

All Semesters

Students conduct research under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Prerequisite: Students must also complete an "Independent Study/Research for Credit" form, available from the SDS advisor in Porter 208A. Permission of a faculty sponsor.

88-398 Independent Study

Fall and Spring

Students conduct independent academic study under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in an independent study should seek out a faculty member whose interests are appropriate to the topic. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-399 Undergraduate Research

Fall and Spring

Students conduct research under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in research should seek out a faculty member whose interests are appropriate to the research. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-405 Risk Perception and Communication

9 units

Throughout their lives, people make decisions about risks that may potentially affect their health, safety, finances, use of technology, and effects on the environment. This course will review the risk perception and communication literature, focusing on theoretical and methodological issues as well as practical implications for educators, public health officials, engineers, economists, and other experts who aim to teach people about risks. We will discuss how to design surveys to increase our understanding of the problems people face when making decisions about specific risks, and how to design communication materials that help people to improve their decisions. We will highlight examples and applications taken from multiple disciplines, including health psychology, adolescent decision making, environmental science, and engineering.

Prerequisites: 36-220 or 36-217 or 36-225 or 36-247 or 36-207 or 70-207 or 36-201

88-406 Behavioral Economics @ Work

Fall: 9 units

Non-profit organizations and businesses are increasingly incorporating insights from behavioral economics and other behavioral sciences into their strategies. This course provides an overview of psychological and economic factors that affect the choices and behavior of individuals within organizations. The course will review empirical research on applications of behavioral insights to a wide range of organizational areas including product pricing, marketing, designing incentives schemes, motivating employees, fundraising, and behavior change. In-class exercises and group projects will supplement the lectures and provide students with hands-on experience in designing solutions to organizations challenges based on behavioral insights. The course emphasizes experimentation as a primary tool for informing organizations decision-making and accurately measuring the effectiveness of behavioral interventions.

Prerequisites: 73-102 or 73-100 or 88-220

88-411 Rise of the Asian Economies

Intermittent: 9 units

For most of the past quarter century, no region of the world has been more economically dynamic than Asia. This course is designed to provide students with the essential knowledge necessary to evaluate opportunities and risks in Asia. The course will use analytical tools drawn from economics and finance, business cases, and guest lectures to focus on the key strengths that sustained economic growth in East Asia for decades, the weaknesses that undermined that growth in the late 1990s, and what lies ahead. The course will also examine Indian economic growth since the early 1980s, and compare India's experience with that of the East Asian economies. A special focus will be placed on recent developments in India and China and the prospects for continued growth in those countries over the next decade.

Prerequisites: 73-100 or 73-150 or 73-102 or 88-220

88-415 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech

Fall: 9 units

Science and Innovation Leadership for the 21st Century introduces students to the fundamental principles surrounding global competitiveness and technological change in the 21st century. The course is broken into three sections. The first section introduces students to competing economic, sociological, and political science theories on the structures supporting technological change. The second section presents the contemporary literature on technological change. The concluding section leverages lessons from the preceding two sections to evaluate national innovation systems, and the factors that lead to national comparative advantage. Students should leave the class able to reflect competently on what the existing literature tells us about the factors influencing global technology competitiveness, and on how modern changes in the structures supporting innovation as well as technology itself may be changing the rules of the game for firms and for nations. The course is open to undergraduate juniors and seniors.

88-418 Negotiation: Strategies and Behavioral Insights

Fall: 9 units

Negotiation is a critical skill that is essential for success in today's world. Decision-makers use negotiation to reach agreements with co-workers, bosses, clients, service providers, subordinates, firms, family, roommates, and friends. Regardless of one's career path, learning how to negotiate effectively is important. This course provides a systematic and insightful approach to negotiation - the art and science of securing agreements between interdependent parties. Through experiential exercises, students will learn to analyze the features of the negotiation environment, develop an understanding of effective negotiation strategies and tactics, and identify the behavioral barriers and psychological factors that may prevent decision-makers from reaching wise agreements. The exercises, which feature negotiations in a variety of contexts including business negotiations, salary negotiations, interpersonal negotiations, and team negotiations, are designed to provide students with an opportunity to practice new strategies in a low-risk environment, receive feedback, and apply new knowledge to subsequent exercises. In-class discussions and lectures will complement the exercises, allowing students to explore and apply theoretical concepts to practical scenarios. This course is appropriate for students of any major who are interested in refining their negotiation skills.

88-419 International Negotiation

Fall: 9 units

Negotiation is a process in which two or more parties undertake a process to resolve conflicting interests. Decision makers use negotiation in a variety of circumstances to reach agreements among countries, among employers and employees, among firms, and among family and friends. International section: The objective of this course is to understand the process of negotiations and how the structure of the negotiation environment affects the outcomes achieved. Students will learn to analyze the features of the negotiation environment, develop an understanding of effective negotiation strategies, and identify the barriers to reaching wise agreements. This course will focus on negotiations in primarily international contexts.

88-435 Decision Science and Policy

Spring: 9 units

Research in the social sciences has extensively investigated how decision makers behave when they encounter many different and difficult decision scenarios. This course serves as an introduction to how relevant research from decision and social sciences can be applied to policy questions encountered by governments (intelligence and policy analysts) and private industry (business strategists and information officers). Topics of operations research, game theory, signal detection theory, and decision theory (heuristics and biases) will be discussed with respect to the application of these theories to improve the performance of individuals and groups within these organizations.

88-444 Public Policy and Regulations

Intermittent: 9 units

Regulations are critical in determining how our society works. How we decide to run our economy, take care of our health, and sustain our environment are all determined through regulations. Everything that you encounter on a daily basis has some regulation lurking behind the scenes. Trying to understand why things are the way they are without understanding the importance, functioning, and limits of regulatory policy is impossible. Despite their importance, regulations are not in the US Constitution. In fact, much to the dismay of some citizens, the "Administrative bureaucracy" that runs the regulatory process is often referred to as the fourth branch of government (on par with the other three: Legislative, Executive, and Judicial). This course will introduce a range of topics related regulatory policies and provide numerous case studies to motivate discussions and comprehension.

88-451 Policy Analysis Senior Project

Spring: 12 units

Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-452 Policy Analysis Senior Project

Fall: 12 units

Students in this course apply the research and analytical methods learned in their other courses to a real-world problem. Students decide how to structure the problem, divide into teams responsible for its different parts, identify and analyze relevant literature, collect data, synthesize their results, and present their conclusions in oral and written form to a review panel of individuals concerned with the problem. Faculty members help them along the way. Performance is based on students' contribution to the process and substance of the class, as observed by the faculty and by their fellow students. One or two such projects is offered every term. A complete list of previous topics is available from the department. Course is open only to seniors in SDS.

88-453 Behavioral Economics Capstone

Spring: 9 units

The Capstone in Behavioral Economics, Policy, and Organizations will work to apply the theories, concepts, and statistical techniques mastered in prior courses to an applied project. Students will work closely both in teams and individually with the instructor on a project that will address a problem posed by an organization or government that behavioral economics can help to solve. Students will work to structure the problem, design an intervention or study, collect and analyze the data, and make recommendations for implementation. Students will manage the project and drive interactions with the client organization.

88-454 Decision Science Capstone

Fall and Spring: 9 units

The Capstone in Decision Science is a seminar that applies the theories, concepts, and statistical techniques mastered in prior courses to an applied project. Students will work closely both in teams and individually with the instructor on a project that will address an applied problem that decision science can help to solve. Students will work to structure the problem, define a focused research question, design a study that addresses the question, collect and analyze the data, and make policy or practice recommendations based on the findings. Students will manage the project, drive the scientific question and approach, and make a formal presentation to a panel of experts.

Prerequisite: 88-302

88-499 Advanced Undergraduate Research

Fall and Spring

Students conduct research at an advanced level under the supervision of a Social and amp; Decision Sciences faculty member. Students who wish to engage in advanced research should seek out a faculty member whose interests are appropriate to the research. Students must also complete an "Independent Study/Research for Credit" form, available from the SDS Advisors in Porter 208A and 208G.

88-505 Undergraduate Internship

All Semesters

An internship is an approved and monitored work experience than can be related to an academic field of study through active reflection and specific learning goals. Students must work at least 10 hours per week for the semester at the internship. Additionally, students will also keep in regular contact with a faculty member in Social and Decision Sciences, who will assign and evaluate academic work. Internships are available for 1-9 units, depending on the type and amount of academic work produced. Students are responsible for finding their own internships and faculty sponsors, although assistance is available in the department. Students must also complete an "Internship Learning Agreement" form, available from the SDS Advisors in Porter 208H and 208G.

Department of Statistics and Data Science

Rebecca Nugent, Department Head

Peter Freeman, Director of Undergraduate Studies

Samantha Nielsen, Associate Director of Academic Programs

Glenn Clune, Academic Program Manager

Amanda Mitchell, Academic Program Manager

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Overview

Uncertainty is inescapable: randomness, measurement error, deception, and incomplete or missing information all complicate our lives. Statistics is the science and art of making predictions and decisions in the face of uncertainty. Statistical issues are central to big questions in public policy, law, medicine, industry, computing, technology, finance, and science. Indeed, the tools of statistics apply to problems in almost every area of human activity where data are collected.

Statisticians have diverse skills in computing, mathematics, decision making, designing experiments, forecasting, and interpreting and communicating analysis results. Moreover, effective statisticians actively collaborate with people in other fields and, in the process, learn about other fields. Statistics & Data Science students who master core concepts and collaboration are highly sought after in the marketplace.

Recent statistics majors at Carnegie Mellon have taken jobs at leading companies in many fields, including the National Economic Research Association, Boeing, Morgan Stanley, Deloitte, Rosetta Marketing Group, Nielsen, Procter & Gamble, Accenture, and Goldman Sachs. Others have taken research positions at the National Security Agency, the U.S. Census Bureau, and the Science and Technology Policy Institute, or worked for Teach for America. Many of our students also go on to graduate study at some of the top programs in the country including Carnegie Mellon, Harvard, MIT, Yale, NYU, Penn, Johns Hopkins, Duke, Michigan, Chicago, Northwestern, Washington, Stanford, and California.

The Department and Faculty

The Department of Statistics & Data Science at Carnegie Mellon University is world-renowned for its contributions to statistical theory and practice. Research in the department spans the gamut from pure mathematics to the hottest frontiers of science. Current research projects are helping make fundamental advances in neuroscience, cosmology, public policy, finance, and genetics.

The faculty members are recognized around the world for their expertise and have garnered many prestigious awards and honors. (For example, three members of the faculty have been awarded the COPSS medal, the highest honor given by professional statistical societies.) At the same time, the faculty is firmly dedicated to undergraduate education. The entire faculty, junior and senior, teach courses at all levels. The faculty are accessible and are committed to involving undergraduates in research.

The Department augments all these strengths with a friendly, energetic working environment and exceptional computing resources. Talented graduate students join the department from around the world, and add a unique dimension to the department's intellectual life. Faculty, graduate students, and undergraduates interact regularly.

How to Take Part

There are many ways to get involved in statistics at Carnegie Mellon:

- The Bachelor of Science in Statistics in the Dietrich College of Humanities and Social Sciences (DC) is a broad-based, flexible program that helps you master both the theory and practice of statistics. The program can be tailored to prepare you for later graduate study in statistics or to complement your interests in almost any field, including psychology, physics, biology, history, business, information systems, and computer science.
- The Minor (or Additional Major) in Statistics is a useful complement to a (primary) major in another department or college. Almost every

field of inquiry must grapple with statistical problems, and the tools of statistical theory and data analysis you will develop in the Statistics minor (or Additional Major) will give you a critical edge.

- The Bachelor of Science in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. Jointly administered by the Department of Statistics & Data Science and the Undergraduate Economics Program, the major's curriculum provides students with a solid foundation in the theories and methods of both fields. (See Dietrich College Interdepartmental Majors as well later in this section)
- The Bachelor of Science in Statistics and Machine Learning is a program housed in the Department of Statistics & Data Science and is jointly administered with the Department of Machine Learning. In this major students take courses focused on skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. The program is geared toward students interested in statistical computation, data science, and "big data" problems.
- The Statistics Concentration and the Operations Research and Statistics Concentration in the Mathematical Sciences Major (see Department of Mathematical Sciences) are administered by the Department of Mathematical Sciences with input from the Department of Statistics & Data Science.
- Non-majors are eligible to take most of our courses, and indeed, they are required to do so by many programs on campus. Such courses offer one way to learn more about the Department of Statistics & Data Science and the field in general.

Curriculum

Statistics consists of two intertwined threads of inquiry: statistical theory and data analysis. The former uses probability theory to build and analyze mathematical models of data in order to devise methods for making effective predictions and decisions in the face of uncertainty. The latter involves techniques for extracting insights from complicated data, designs for accurate measurement and comparison, and methods for checking the validity of theoretical assumptions. Statistical theory informs data analysis and vice versa. The Department of Statistics & Data Science curriculum follows both of these threads and helps students develop required skills.

Throughout the sections of this catalog, we describe the requirements for the Major in Statistics (the core major as well as the Mathematics and Neuroscience tracks), followed by the requirements for the Major in Economics and Statistics, the Major in Statistics and Machine Learning, and the Minor in Statistics.

Note: We recommend that you use the information provided below as a general guideline, and then schedule a meeting with a Statistics Undergraduate Advisor (statadvising@stat.cmu.edu) to discuss the requirements in more detail, and build a program that is tailored to your strengths and interests.

B.S. in Statistics

Glenn Clune, *Academic Program Manager*

Location: Baker Hall 129

statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Bachelor of Science program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics are detailed below and are organized by categories #1-7.

Curriculum

1. Mathematical Foundations (Prerequisites)

29-42 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

And one of the following three courses:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

And one of the following three courses:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Notes:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra**

Complete *one* of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis**36-45 units**

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)**Beginning***

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with credit for 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |

* Or an extra Advanced Data Analysis Elective

** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required

Advanced Data Analysis Elective

Choose *one* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Students can also take a second 36-46x (see section #5).

and take the following *two* courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Sequence 2 (For students beginning later in their college career)**Advanced Data Analysis Electives**

Choose *two* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following two courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I * | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

And one of the following three courses:

| | | |
|--------|---|---|
| 36-236 | Probability and Statistical Inference II ** | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

*It is possible to substitute 36-218, 36-219, 36-225, or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent), and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the following two courses:

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Complete the following course:

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.). The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose *one* of the **36-46x** courses (which are 9 units).

Note: All 36-46x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9-12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with the Statistics Undergraduate Advisor.

| | | |
|--------|---|----|
| 15-121 | Introduction to Data Structures | 10 |
| 15-122 | Principles of Imperative Computation | 12 |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 15-388 | Practical Data Science | 9 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-260 | Differential Equations | 9 |
| 21-292 | Operations Research I | 9 |
| 21-301 | Combinatorics | 9 |
| 21-355 | Principles of Real Analysis I | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-310 | Formal Logic | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |

Note: Additional prerequisites are required for some of these courses. Students should carefully check the course descriptions to determine if additional prerequisites are necessary.

7. Concentration Area

Self-Defined Concentration Area (with advisor's approval) **36 UNITS**

The power of statistics, and much of the fun, is that it can be applied to answer such a wide variety of questions in so many different fields. A critical part of statistical practice is understanding the questions being asked so that appropriate methods of analysis can be used. Hence, a critical part of statistical training is to gain experience applying abstract tools to real problems.

The Concentration Area is a set of four related courses outside of Statistics & Data Science that prepares the student to deal with statistical aspects of problems that arise in another field. These courses are usually drawn from a *single* discipline of interest to the student and must be approved by the Statistics Undergraduate Advisor. While these courses are not in Statistics & Data Science, the concentration area must complement the overall degree.

For example, students intending to pursue careers in the health or biomedical sciences could take further courses in biology or chemistry, or students intending to pursue graduate work in statistics could take further courses in advanced mathematics.

The concentration area can be fulfilled with a minor or additional major, but not all minors and additional majors fulfill this requirement. Please make sure to consult the Undergraduate Statistics Advisor *prior* to pursuing courses for the concentration area. Once the concentration area is approved, any changes made to the previously agreed upon coursework require re-approval by the Undergraduate Advisor.

Concentration Approval Process

- Submit the below materials to the Undergraduate Statistics Advisor
 - List of possible coursework to fulfill the concentration*
 - 150-200 word essay describing how the proposed courses complement the B.S. in Statistics degree.

* These courses can be amended later but must be re-approved by the Statistics Undergraduate Advisor if amended.

* Note: The concentration/track requirement is only for students whose *primary* major is statistics and has no other additional major or minor. The

requirement does not apply for students who pursue an *additional* major in statistics.

| | |
|--------------------------------------|-----------------------|
| Total number of units for the major | 156-183* Units |
| Total number of units for the degree | 360 Units |

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in statistics or biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track** or to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional Major in Statistics

Students who elect the B.S. in Statistics as a second or third major must fulfill all Statistics degree requirements except for the Concentration Area requirement. Majors in many other programs would naturally complement a statistics major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least five statistics courses that do not count for their primary major. If students do not have at least five, they will need to take additional advanced data analysis electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for the B.S. in Statistics.

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research, 36-493 Sports Analytics Capstone, or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p. 322).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral

researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics. However, keep in mind that the program is flexible enough to support *many* other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 1.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the beginning data analysis sequence). This schedule has more emphasis on statistical theory and probability.

Schedule 1

| First-Year | | Second-Year | |
|----------------------------|---|--|---|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-111 Calculus I | 21-112 Calculus II | 21-256 Multivariate Analysis | 36-350 Statistical Computing |
| ----- | One of the following two courses: | Course toward concentration | 21-240 Matrix Algebra with Applications |
| ----- | 15-110 Principles of Computing | ----- | ----- |
| ----- | 15-112 Fundamentals of Programming and Computer Science | ----- | ----- |

| Third-Year | | Fourth-Year | |
|--|---|-----------------------------|-----------------------------|
| Fall | Spring | Fall | Spring |
| 36-401 Modern Regression | 36-402 Advanced Methods for Data Analysis | Course toward concentration | Course toward concentration |
| 36-3xx or 36-4xx Advanced Data Analysis Elective | 36-46x Special Topics course | ----- | ----- |
| Course toward concentration | Course toward concentration | ----- | ----- |
| ----- | ----- | ----- | ----- |

Schedule 2

| First-Year | | Second-Year | |
|---|---|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 36-200 Reasoning with Data | One of the following two courses: | ----- | 21-240 Matrix Algebra with Applications |
| ----- | 15-110 Principles of Computing | ----- | ----- |
| ----- | 15-112 Fundamentals of Programming and Computer Science | ----- | ----- |

| Third-Year | | Fourth-Year | |
|--|---|-----------------------------|--|
| Fall | Spring | Fall | Spring |
| 36-350 Statistical Computing | 36-402 Advanced Methods for Data Analysis | 36-46x Special Topics | Course toward concentration |
| 36-401 Modern Regression | Course toward concentration | Course toward concentration | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| 36-3xx or 36-4xx Advanced Data Analysis Elective | ----- | ----- | ----- |
| Course toward concentration | ----- | ----- | ----- |

B.S. in Statistics (Mathematical Sciences Track)

Glenn Clune, *Academic Program Manager*

Location: Baker Hall 129

statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Bachelor of Science program develop and master a wide array of skills in computing, mathematics, statistical theory, and the

interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics (Mathematical Sciences Track) are detailed below and are organized by categories #1-#7.

Curriculum

1. Mathematical Foundations (Prerequisites) 29-42 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

And one of the following three courses:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

And one of the following three courses:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Notes:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra**

Complete *one* of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis 36-45 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |

*Or an extra Advanced Data Analysis Elective

** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required

Advanced Data Analysis Elective

Choose *one* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Students can also take a second 36-46x (see section #5).

and take the following *two* courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Sequence 2 (For students beginning later in their college career)

Advanced

Choose *two* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |

| | | |
|--------|---|---|
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following two courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I * | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

And one of the following three courses:

| | | |
|--------|---|---|
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-236 | Probability and Statistical Inference II ** | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

*It is possible to substitute 36-218, 36-219, 36-225, or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced (students need prior approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent), and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the following two courses:

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Complete the following course:

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.). The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose one of the **36-46x** courses (which are 9 units).

Note: All 36-46x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9-12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with the Statistics Undergraduate Advisor.

| | | |
|--------|---|----|
| 15-121 | Introduction to Data Structures | 10 |
| 15-122 | Principles of Imperative Computation | 12 |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 15-388 | Practical Data Science | 9 |
| 21-260 | Differential Equations | 9 |
| 21-292 | Operations Research I | 9 |
| 21-301 | Combinatorics | 9 |
| 21-355 | Principles of Real Analysis I | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-310 | Formal Logic | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |

Note: Additional prerequisites are required for some of these courses. Students should carefully check the course descriptions to determine if additional prerequisites are necessary.

Mathematical Statistics Track 46-52 units

| | | |
|--------|--------------------------------------|----|
| 21-127 | Concepts of Mathematics | 12 |
| 21-355 | Principles of Real Analysis I | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |

And two of the following:

| | | |
|-----------|---|----|
| 21-228 | Discrete Mathematics | 9 |
| 21-257 | Models and Methods for Optimization | 9 |
| or 21-292 | Operations Research I | |
| 21-301 | Combinatorics | 9 |
| 21-344 | Numerical Linear Algebra | 9 |
| 21-356 | Principles of Real Analysis II | 9 |
| 21-373 | Algebraic Structures | 9 |
| 36-700 | Probability and Mathematical Statistics | 12 |

Total number of units for the major **167-199 Units***

Total number of units for the degree **360 Units**

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus

requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track**.

Additional Major in Statistics (Mathematical Science Track)

Students who elect the B.S. in Statistics (Mathematical Science Track) as an additional major must fulfill all Statistics (Mathematical Science Track) degree requirements. With respect to double-counting courses, it is departmental policy that students must have at least five statistics courses that do not count for their primary major. If students do not have at least five, they typically take additional advanced data analysis electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a B.S. in Statistics (Mathematical Science Track).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research, 36-493 Sports Analytics Capstone, or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p. 322).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics (Mathematical Sciences Track). However, keep in mind that the program is flexible enough to support many other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 1.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the intermediate data analysis course). This schedule has more emphasis on statistical theory and probability.

SCHEDULE 1

| First-Year | | Second-Year | |
|----------------------------|--|---|---|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-111 Calculus I | 21-256 Multivariate Analysis | 21-127 Concepts of Mathematics | 36-350 Statistical Computing |
| ----- | 21-112 Calculus II | One of the two following courses: | 21-240 Matrix Algebra with Applications |
| ----- | ----- | 15-110 Principles of Computing | ----- |
| ----- | ----- | 15-112 Fundamentals of Programming and Computer Science | ----- |

| Third-Year | | Fourth-Year | |
|--------------------------|--|--------------------------------------|---|
| Fall | Spring | Fall | Spring |
| 36-401 Modern Regression | 36-402 Advanced Methods for Data Analysis | 36-46x Special Topics | 36-410 Introduction to Probability Modeling |
| Math Track Elective | 36-3xx or 36-4xx Advanced Data Analysis Elective | 21-355 Principles of Real Analysis I | Math Track Elective |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

Schedule 2

| First-Year | | Second-Year | |
|---|---|--|--|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 21-256 Multivariate Analysis | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-120 Differential and Integral Calculus | One of the two following courses: | 21-127 Concepts of Mathematics | 21-241 Matrices and Linear Transformations |
| ----- | 15-110 Principles of Computing | ----- | ----- |
| ----- | 15-112 Fundamentals of Programming and Computer Science | ----- | 36-3xx or 36-4xx Advanced Data Analysis Elective |

| Third-Year | | Fourth-Year | |
|------------------------------|--|--------------------------------------|---|
| Fall | Spring | Fall | Spring |
| 36-350 Statistical Computing | 36-402 Advanced Methods for Data Analysis | 36-46x Special Topics | 36-410 Introduction to Probability Modeling |
| 36-401 Modern Regression | 36-3xx or 36-4xx Advanced Data Analysis Elective | 21-355 Principles of Real Analysis I | Math Track Elective |
| Math Track Elective | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

B.S. in Statistics (Statistics and Neuroscience Track)

Glenn Clune, *Academic Program Manager*

Location: Baker Hall 129

statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Bachelor of Science program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. The requirements for the B.S. in Statistics (Neuroscience Track) are detailed below and are organized by categories #1-#7.

Curriculum

1. Mathematical Foundations (Prerequisites) 29-42 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics & Data Science.

Calculus*

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|---|------------------------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |
| And one of the following three courses: | | |
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|---|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| And one of the following three courses: | | |
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Notes:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Linear Algebra**

Complete *one* of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis**36-45 units**

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfies the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering and architecture.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)**Beginning***

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |

*Or an extra Advanced Data Analysis Elective

** Must take prior to 36-401, if not, an additional Advanced Data Analysis Elective is required

Advanced Data Analysis Electives

Choose *one* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Students can also take a second 36-46x (see section #5).

and take the following *two* courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Sequence 2 (For students beginning later in their college career)**Advanced Data Analysis Electives**

Choose *two* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

and take the following *two* courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses:

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

and one of the following three courses:

| | | |
|--------|---|---|
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-236 | Probability and Statistical Inference II ** | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

*It is possible to substitute 36-218, 36-219, 36-225 or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous probability theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 (honors course) in place of 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comment:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent) and 36-401.

4. Statistical Computing 19 to 21 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing). Within the larger domain of data science, the use of the programming language Python is also ubiquitous, and thus we require all majors to gain, at a minimum, basic competency in the language by taking either Principles of Computing, or Fundamentals of Programming and Computer Science. We would advise those students who are considering receiving course credit for one of these two courses given their score on the AP Computer Science A exam to actually take one (or both) of them at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

Take one of the two following courses:

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Complete the following course:

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

5. Special Topics 9 units

The Department of Statistics & Data Science offers advanced courses that focus on specific statistical applications or advanced statistical methods. These courses are numbered 36-46x (36-461, 36-462, etc.). The objective of the course is to expose students to important topics in statistics and/or interesting applications which are not part of the standard undergraduate curriculum. Note that all Special Topics are not offered every semester, and new Special Topics are regularly added.

To satisfy the Special Topics requirement choose *one* of the **36-46x** courses (which are 9 units).

Note: All 36-46x courses require 36-401 as a prerequisite or corequisite.

6. Statistical Elective 9-12 units

Students are required to take one elective which can be within or outside the Department of Statistics & Data Science. **Courses within Statistics & Data Science** can be any 300 or 400 level course (that is not used to satisfy any other requirement for the statistics major).

The following is a partial list of **courses outside Statistics & Data Science** that qualify as electives as they provide the intellectual infrastructure that will advance the student's understanding of statistics and its applications. Other courses may qualify as well; consult with the Statistics Undergraduate Advisor.

| | | |
|--------|---|----|
| 15-121 | Introduction to Data Structures | 10 |
| 15-122 | Principles of Imperative Computation | 12 |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 15-388 | Practical Data Science | 9 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-260 | Differential Equations | 9 |
| 21-292 | Operations Research I | 9 |
| 21-301 | Combinatorics | 9 |
| 21-355 | Principles of Real Analysis I | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-310 | Formal Logic | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |

Statistics and Neuroscience Track 45-54 UNITS

| | | |
|--------|-----------------------------------|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

And three electives (at least one from Methodology and Analysis and at least one within the Neuroscience Background listed below):

Methodology and Analysis

| | | |
|-----------|--|----|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 18-290 | Signals and Systems | 12 |
| 36-700 | Probability and Mathematical Statistics | 12 |
| 42/86-631 | Neural Data Analysis | 12 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |

Neuroscience Background

| | | |
|--------|---|---|
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 15-386 | Neural Computation | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |

Total Number of Units for the Major: 165-201* Units

Total Number of Units for the Degree: 360 Units

*Note: This number can vary depending on the courses chosen for the concentration area that a student takes. Speak with an academic advisor for more details.

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 by the end of their freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Biostatistics (or related programs) after completing their undergraduate degree are strongly recommended to pursue the **Mathematical Statistics Track** or to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional Major in Statistics (Neuroscience Track)

Students who elect the B.S. in Statistics (Neuroscience Track) as an additional major must fulfill all Statistics (Neuroscience Track) degree requirements. With respect to double-counting courses, it is departmental policy that students must have at least five statistics courses that do not count for their primary major. If students do not have at least five, they take additional advanced data analysis electives.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for the B.S. in Statistics (Neuroscience Track).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research, 36-493 Sports Analytics Capstone, or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p. 322).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample programs illustrate three (of many) ways to satisfy the requirements for the B.S. in Statistics (Neuroscience Track). However, keep in mind that the program is flexible enough to support many other possible schedules and to emphasize a wide variety of interests.

The first schedule uses calculus sequence 2.

The second schedule is an example of the case when a student enters the program through 36-235 and 36-236 (and therefore skips the intermediate data analysis course). This schedule has more emphasis on statistical theory and probability.

schedule 1

| First-Year | | Second-Year | |
|---|---|--|---|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 85-219 Foundations of Brain and Behavior | 36-350 Statistical Computing |
| 85-211 Cognitive Psychology | And one of the following two courses: | ----- | 21-240 Matrix Algebra with Applications |
| ----- | 15-110 Principles of Computing | ----- | ----- |
| ----- | 15-112 Fundamentals of Programming and Computer Science | ----- | ----- |

| Third-Year | | Fourth-Year | |
|-----------------------------|---|-----------------------------|--|
| Fall | Spring | Fall | Spring |
| 36-401 Modern Regression | 36-402 Advanced Methods for Data Analysis | 36-46x Special Topics | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| Neuroscience Track Elective | Neuroscience Track Elective | Neuroscience Track Elective | ----- |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

Schedule 2

| First-Year | | Second-Year | |
|----------------------------|---|------------------------------|--|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 36-202 Methods for Statistics & Data Science | 21-256 Multivariate Analysis | 21-240 Matrix Algebra with Applications |
| 21-111 Calculus I | 21-112 Calculus II | 85-211 Cognitive Psychology | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| ----- | Take one of the following two courses: | ----- | ----- |
| ----- | 15-110 Principles of Computing | ----- | ----- |
| ----- | 15-112 Fundamentals of Programming and Computer Science | ----- | ----- |

| Third-Year | | Fourth-Year | |
|--|---|--|---|
| Fall | Spring | Fall | Spring |
| 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II | 36-401 Modern Regression | 36-402 Advanced Methods for Data Analysis |
| 85-219 Foundations of Brain and Behavior | Neuroscience Track Elective | 36-350 Statistical Computing | 36-46x - Special Topics |
| ----- | ----- | Neuroscience Track Elective | Neuroscience Track Elective |
| ----- | ----- | 36-3xx or 36-4xx Advanced Data Analysis Elective | ----- |

B.S. in Economics and Statistics

Amanda Mitchell, *Statistics & Data Science Academic Program Manager*
 Stephen Pajewski, *Economics Senior Academic Advisor and Program Manager*

Statistics & Data Science Location: Baker Hall 129
 statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Economics Location: Tepper 2400
 econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong

analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

Curriculum

The requirements for the B.S. in Economics and Statistics are the following:

1. MATHEMATICAL FOUNDATIONS (PREREQUISITES) 29-42 UNITS

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Economics and Statistics.

CALCULUS

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

SEQUENCE 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

SEQUENCE 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

NOTES:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 54 units

2. Economics Foundations 18 UNITS

Take one of the following courses:

| | | |
|--------|---|---|
| 73-102 | Principles of Microeconomics * | 9 |
| 73-104 | Principles of Microeconomics Accelerated ** | 9 |

Take the following course:

| | | |
|--------|------------------------------|---|
| 73-103 | Principles of Macroeconomics | 9 |
|--------|------------------------------|---|

*Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102

**This course requires students to complete a 4 or 5 on the AP Microeconomics exam or qualifying score on the IB/Cambridge Exams. 73-104 will substitute for any 73-102 prerequisite requirement in other courses. 73-104 is a more rigorous introduction to microeconomics, is taught at a faster pace than 73-102, and dives a bit deeper into key topics. It is designed for students who have prior knowledge to fundamental economic concepts through AP/IB/Cambridge coursework. Enrollment in 73-104 requires special permission. Students who wish

to take this course should add themselves to the 73-104 waitlist once registration opens. The Tepper School will verify the advancement placement scores and will enroll students in 73-104

3. Statistical Foundations 36 UNITS

DATA ANALYSIS

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |

* Or extra data analysis course in Statistics

** Must take prior to 36-401 Modern Regression, if not, an additional Advanced Statistics Elective is required.

Advanced Statistics Elective

Choose *two* of the following courses:

| | | |
|--------|--|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |

| | | |
|--------|---|---|
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Sequence 2 (For students beginning later in their college career)

Advanced Statistics Electives

Choose *three* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core

136-139 units

1. Economics Core 45 UNITS

| | | |
|--------|---|---|
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 73-270 | Professional Communication for Economists | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |
| 73-374 | Econometrics II | 9 |

2. Statistics Core 36 UNITS

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I ^{**} | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

Take one of the following courses:

| | | |
|--------|--|---|
| 36-236 | Probability and Statistical Inference II ^{**} | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

Take both of the following courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-235 (or equivalents), 36-236 or 36-326 and 36-401.

#It is possible to substitute 36-218, 36-219, 36-225 or 21-325 for 36-235. 36-235 is the standard introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 for 36-236. 36-236 is the standard introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

3. Statistical Computing 19-21 UNITS

Take one of the following two courses:

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Complete the following course:

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-313, 36-315, 36-318, 36-46x, 36-490, 36-493 or 36-497).

Total number of units for the major 219-235 Units

Total number of units for the degree 360 Units

Professional Development

While not required, students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is , a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as an additional major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Economics (73-xxx) and three Statistics (36-xxx)] that do *not* count for their primary major. If students do not have at least three ECON and three STA classes, they will need to take additional advanced data analysis or economics electives, depending on where the double-counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Substitutions and Waivers

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the

program is flexible and can support other possible schedules (see footnotes below the schedule).

| First-Year | | Second-Year | |
|---|--|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 36-200 Reasoning with Data | 21-256 Multivariate Analysis | 73-230 Intermediate Microeconomics | 21-240 Matrix Algebra with Applications |
| 73-102 Principles of Microeconomics | 73-103 Principles of Macroeconomics | | 73-240 Intermediate Macroeconomics |
| 15-110 Principles of Computing | ----- | 73-265 Economics and Data Science | 73-274 Econometrics I |
| | ----- | ----- | ----- |

| Third-Year | | Fourth-Year | |
|------------------------------|--|--|--|
| Fall | Spring | Fall | Spring |
| 36-350 Statistical Computing | 36-402 Advanced Methods for Data Analysis | 36-3xx or 36-4xx Advanced Data Analysis Elective | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| 36-401 Modern Regression | 73-270 Professional Communication for Economists | Economics Elective | Economics Elective |
| 73-374 Econometrics II | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students are advised to add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

B.S. in Statistics and Machine Learning

Amanda Mitchell, *Academic Program Manager*

Location: Baker Hall 129
 statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Students in the Statistics and Machine Learning program develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, Statistics and Machine Learning majors gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science, or "Big Data" problems. The requirements for the B.S. in Statistics and Machine Learning are detailed below and are organized by categories.

Curriculum

1. Mathematical Foundations (Prerequisites) 51-64 units

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Statistics and Machine Learning.

Calculus*

Complete one of the following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

and one of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

and one of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Notes:

- Passing the Mathematical Sciences 21-120 assessment test is an acceptable alternative to completing 21-120

Integration and Approximation

| | | |
|--------|-------------------------------|----|
| 21-122 | Integration and Approximation | 10 |
|--------|-------------------------------|----|

Linear Algebra**

Complete one of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

* It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be completed before taking 36-401 Modern Regression.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

Mathematical Theory

| | | |
|--------|-------------------------|----|
| 21-127 | Concepts of Mathematics | 12 |
|--------|-------------------------|----|

2. Data Analysis 45-54 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the Dietrich College Core Requirement in Statistical Reasoning. One of these courses is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering and architecture.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose one of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor.

Intermediate*

Choose one of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |

*Or an extra Advanced Data Analysis Elective

**Must take prior to 36-401 or will need to take an additional Advanced Data Analysis Elective

Advanced Data Analysis Electives

Choose two of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

All Special Topics are not offered every semester. They are on a rotation and new Special Topics are regularly added.

and take the following two courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis Electives

Choose three of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

All Special Topics are not offered every semester. They are on a rotation and new Special Topics are regularly added.

and take the following two courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following two courses**:

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I * | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

And one of the three following courses:

| | | |
|--------|---|---|
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-236 | Probability and Statistical Inference II ** | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

*It is possible to substitute 36-218, 36-219, 36-225 or 21-325 for 36-235. 36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.)

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who take 36-235 are expected to take 36-236 to complete their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comments:

(i) In order to meet the prerequisite requirements, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent) and 36-401.

4. Statistical Computing 9 units

Fundamental to the practice of statistics and data science is the ability to effectively code data processing and analysis tasks. Within the domain of statistics, the use of the programming language R is ubiquitous, and thus we expose students to it throughout the curriculum (and in depth in Statistical Computing).

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

5. Machine Learning/Computer Science 57-60 units

Statistical modeling in practice nearly always requires computation in one way or another. Computational algorithms are sometimes treated as "black boxes," whose innards the statistician need not pay attention to. But this attitude is becoming less and less prevalent, and today there is much to be gained from a strong working knowledge of computational tools. Understanding the strengths and weaknesses of various methods allows the data analyst to select the right tool for the job; understanding how they can be adapted to work in new settings greatly extends the realm of problems that he/she can solve. While all majors in Statistics & Data Science are given solid grounding in computation, extensive computational training is really what sets the B.S. in Statistics and Machine Learning program apart. Note that we would advise those students who are considering receiving course credit for Fundamentals of Programming and Computer Science given their score on the AP Computer Science A exam to actually take the course at Carnegie Mellon instead, as within data science as a whole Python is far more widely used than Java.

| | | |
|-----------|--|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-351 | Algorithms and Advanced Data Structures | 12 |
| or 15-451 | Algorithm Design and Analysis | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |

and take one of the following Machine Learning Advanced Electives:

| | | |
|--------|---------------------------------------|----|
| 05-434 | Machine Learning in Practice | 12 |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-703 | Deep Reinforcement Learning & Control | 12 |

| | | |
|--------|---|----|
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-605 | Machine Learning with Large Datasets | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-707 | Advanced Deep Learning | 12 |
| 11-344 | Machine Learning in Practice | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 11-661 | Language and Statistics | 12 |
| 11-761 | Language and Statistics | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 15-387 | Computational Perception | 9 |
| 16-311 | Introduction to Robotics | 12 |
| 16-385 | Computer Vision | 12 |
| 16-720 | Computer Vision | 12 |

*PhD level ML course as approved by Statistics advisor
 ** Independent research with an ML faculty member as approved by Statistics Advisor
 ***This is not an exhaustive list. Please contact your Academic Advisor if there is a course you are considering taking that is not on this list.

| | |
|---|----------------------|
| Total number of units for the major | 180-205 Units |
| Total number of units for the degree | 360 Units |

Recommendations

Students in the Dietrich College of Humanities and Social Sciences who wish to major or minor in Statistics are advised to complete both the calculus requirement (one Mathematical Foundations calculus sequence) and the Beginning Data Analysis course 36-200 Reasoning with Data by the end of their Freshman year.

The linear algebra requirement is a prerequisite for the course 36-401. It is therefore essential that students complete this requirement by their junior years at the latest.

Recommendations for Prospective Ph.D. Students

Students interested in pursuing a Ph.D. in Statistics or Machine Learning (or related programs) after completing their undergraduate degree are strongly recommended to take additional Mathematics courses. Although 21-240 Matrix Algebra with Applications is recommended for Statistics majors, students interested in PhD programs should consider taking 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory instead. Additional courses to consider are 21-228 Discrete Mathematics, 21-341 Linear Algebra, 21-355 Principles of Real Analysis I, and 21-356 Principles of Real Analysis II.

Additional experience in programming and computational modeling is also recommended. Students should consider taking more than one course from the list of Machine Learning electives provided under the Computing section.

Additional Major in Statistics and Machine Learning

Students who elect Statistics and Machine Learning as a second or third major must fulfill *all* degree requirements.

With respect to double-counting courses, it is departmental policy that students must have at least six courses (three Computer Science/Machine Learning and three Statistics) that do *not* count for their primary major. If students do not have at least six, they will need to take additional advanced data analysis or ML electives, depending on where the double counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other

major's requirements overlap with the requirements for the B.S. in Statistics and Machine Learning.

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics and Machine Learning.

Research

The Statistics & Data Science program encourages students to gain research experience. Opportunities within the department include Summer Undergraduate Research Apprenticeships (SURA), run in association with the university's Office of Undergraduate Research and Scholar Development, and the departmental capstone courses 36-490 Undergraduate Research, 36-493 Sports Analytics Capstone, or 36-497 Corporate Capstone Project. (Note that these courses require an application.) Additionally, students can pursue independent study. For those students who maintain a quality point average of 3.25 overall or above, there is also the Dietrich College Senior Honors Program (p. 322).

The faculty in the Statistics & Data Science department largely work within the domains of statistical theory and methodological development, areas that require advanced mathematical training. Thus we encourage students to search broadly for research opportunities: faculty, post-doctoral researchers, and graduate students in many departments throughout the university have data to analyze and would welcome the help of undergraduate statistics students.

Sample Programs

The following sample program illustrates one way to satisfy the requirements for the B.S. in Statistics and Machine Learning. Keep in mind that the program is flexible and can support other possible schedules (see footnotes below the schedule). Sample program 1 is for students who have not satisfied the basic calculus requirements. Sample program 2 is for students who have satisfied the basic calculus requirements and choose option 2 for their data analysis courses (see section #2)

Schedule 1

| First-Year | | Second-Year | |
|---|---|--|---|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 21-122 Integration and Approximation | 21-241 Matrices and Linear Transformations |
| ----- | 15-112 Fundamentals of Programming and Computer Science | 21-127 Concepts of Mathematics | 15-122 Principles of Imperative Computation |
| ----- | ----- | ----- | 36-350 Statistical Computing |
| ----- | ----- | ----- | ----- |

| Third-Year | | Fourth-Year | |
|--------------------------|--|---|--|
| Fall | Spring | Fall | Spring |
| 36-401 Modern Regression | 36-402 Advanced Methods for Data Analysis | 10-301 Introduction to Machine Learning (Undergrad) | Machine Learning Advanced Elective |
| ----- | 15-351 Algorithms and Advanced Data Structures | 36-3xx or 36-4xx Advanced Data Analysis Elective | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Schedule 2

| First-Year | | Second-Year | |
|---|--------------------------------|--|--|
| Fall | Spring | Fall | Spring |
| 36-200 Reasoning with Data | 21-127 Concepts of Mathematics | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 21-256 Multivariate Analysis | ----- | 15-122 Principles of Imperative Computation | 21-241 Matrices and Linear Transformations |
| 15-112 Fundamentals of Programming and Computer Science | ----- | ----- | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

| Third-Year | | Fourth-Year | |
|------------------------------|--|---|--|
| Fall | Spring | Fall | Spring |
| 36-350 Statistical Computing | 36-402 Advanced Methods for Data Analysis | 10-301 Introduction to Machine Learning (Undergrad) | Machine Learning Advanced Elective |
| 36-401 Modern Regression | 15-351 Algorithms and Advanced Data Structures | 36-3xx or 36-4xx Advanced Data Analysis Elective | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

*In each semester, "-----" represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

The Minor in Statistics

Sylvie Aubin, *Undergraduate Academic Advisor*
 Location: Baker Hall 129
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The Minor in Statistics develops skills that complement major study in other disciplines. The program helps the student master the basics of statistical theory and advanced techniques in data analysis. This is a good choice for deepening understanding of statistical ideas and for strengthening research skills.

In order to get a minor in Statistics a student must satisfy all of the following requirements:

1. Mathematical Foundations (Prerequisites) 29-41 units

Calculus*:

Complete *one* of the following two sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Note: Passing the Mathematical Sciences 21-120 assessment test if an acceptable alternative to completing 21-120.

Linear Algebra:

Complete *one* of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

*It is recommended that students complete the calculus requirement during their freshman year.

**The linear algebra requirement needs to be complete before taking 36-401 Modern Regression or 36-46X Special Topics.

21-241 and 21-242 are intended only for students with a very strong mathematical background.

2. Data Analysis

36 units

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. One of these courses is therefore recommended for students in the College. (Note: A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement). Other courses emphasize examples in engineering and architecture (36-220), and the laboratory sciences (36-247).

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis and Methodology courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning Data Analysis*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 36-247 | Statistics for Lab Sciences | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. Other courses emphasize examples in engineering and Architecture (36-220) and the laboratory sciences (36-247).

Intermediate Data Analysis*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |

*The Beginning and Intermediate Data Analysis sequence (i.e. 36-200 and 36-202, or equivalents as listed above) can be replaced with an *additional* Advanced Analysis and Methodology course, shown below in Sequence 2.

**Must take the Intermediate Data Analysis requirement prior to 36-401, if not, an additional Advanced Analysis and Methodology course is required.

Advanced Data Analysis and Methodology

Take the following course:

| | | |
|--------|-------------------|---|
| 36-401 | Modern Regression | 9 |
|--------|-------------------|---|

and *one* of the following courses:

| | | |
|--------|--|---|
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |

| | | |
|--------|---|---|
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Special Topics rotate and new ones are regularly added.

Sequence 2 (For students beginning later in their college career)

Advanced Data Analysis and Methodology

Take the following course:

| | | |
|--------|-------------------|---|
| 36-401 | Modern Regression | 9 |
|--------|-------------------|---|

and take two of the following courses (one of which must be 400-level):

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Special Topics rotate and new ones are regularly added.

3. Probability Theory and Statistical Theory 18 units

The theory of probability gives a mathematical description of the randomness inherent in our observations. It is the language in which statistical models are stated, so an understanding of probability is essential for the study of statistical theory. Statistical theory provides a mathematical framework for making inferences about unknown quantities from data. The theory reduces statistical problems to their essential ingredients to help devise and evaluate inferential procedures. It provides a powerful and wide-ranging set of tools for dealing with uncertainty.

To satisfy the theory requirement take the following *two* courses:

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I * | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

And one of the following three courses:

| | | |
|--------|---|---|
| 36-236 | Probability and Statistical Inference II ** | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

*It is possible to substitute 36-218, 36-219, 36-225 or 21-325 for 36-235. (36-235 is the standard (and recommended) introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced (students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.) 36-326 is not offered every semester/year but can be substituted for 36-226 and is considered an honors course.

**It is possible to substitute 36-226 or 36-326 (honors course) for 36-236. 36-236 is the standard (and recommended) introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

Comments:

(i) In order to be in good standing and to continue with the minor, a grade of at least a C is required in 36-235 (or equivalent), 36-236 (or equivalent), and 36-401.

Total number of units required for the minor 83 Units

Double Counting

With respect to double-counting courses, it is departmental policy that students must have at least three statistics courses (36-xxx) that do not count for their primary major. If students do not have at least three, they need to take additional advanced electives. Make sure to consult your Statistics Minor advisor regarding double counting.

Sample Programs for the Minor

The following two sample programs illustrates two (of many) ways to satisfy the requirements of the Statistics Minor. Keep in mind that the program is flexible and can support many other possible schedules.

The first schedule uses calculus sequence 1, and 36-202 to satisfy the intermediate data analysis requirement. The second schedule is an example of the case when a student enters the Minor through 36-235 and 36-236 (and therefore skips the beginning data analysis course). The schedule uses calculus sequence 2, and an advanced data analysis elective (to replace the beginning data analysis course).

Schedule 1

| First-Year | | Second-Year | |
|----------------------------|--------------------|--|---|
| Fall | Spring | Fall | Spring |
| 21-111 Calculus I | 21-112 Calculus II | 36-202 Methods for Statistics & Data Science | 21-240 Matrix Algebra with Applications |
| 36-200 Reasoning with Data | | 21-256 Multivariate Analysis | |

| Third-Year | | Fourth-Year | |
|--|---|--------------------------|-------------------------|
| Fall | Spring | Fall | Spring |
| 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II | 36-401 Modern Regression | Any 36-4xx level course |

Schedule 2

| First-Year | | Second-Year | |
|---|------------------------------|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 36-200 Reasoning with Data | | | 21-240 Matrix Algebra with Applications |

| Third-Year | | Fourth-Year | |
|--------------------------|--|--|--------|
| Fall | Spring | Fall | Spring |
| 36-401 Modern Regression | 36-3xx or 36-4xx Advanced Data Analysis Elective | One 36-4xx Advanced Methodology Course | |

Statistics & Data Science Dietrich Senior Honors Thesis

Eligibility

Eligibility is determined by Dietrich College. Students who are eligible will be notified prior to their senior year.

Dietrich College Requirements (<https://www.cmu.edu/dietrich/students/undergraduate/programs/senior-honors/>):

- Students *must have a major in Dietrich College*, either as a primary or an additional major; or be in the BHA (<https://www.cmu.edu/interdisciplinary/programs/bha.html>) program.

- Cumulative QPA through the end of the junior year of at least 3.25 overall, and 3.50 in the Dietrich College major associated with the proposed project.
- Departmental sponsorship in the form of an agreement by a faculty member to serve as advisor for the 2-semester/18 unit Honors project (graduate students may not serve as advisors; adjunct faculty may do so, but only in collaboration with a regular faculty member), and approval by the department head.

Statistics & Data Science Requirements Overview

The below guidelines apply to any Statistics & Data Science students who are doing an honors thesis that has been *approved through the Statistics & Data Science department* (i.e. our department signs off on the thesis paperwork). If you are a Stat & DS student pursuing a Dietrich senior honors thesis through another department (i.e. a different department than Stat & DS is signing off on it) then these guidelines do not apply to you.

In order to be approved for a thesis with the Stat & DS department the project needs to have a significant statistical component. This will be discussed and confirmed during the proposal approval phase of applying.

Honors Thesis Timeline

Senior Year - Fall Semester

The Dietrich College senior honors thesis is a year-long project. As such, after the fall semester of a student's senior year a progress report will be due to Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), for review.

Progress Paper Requirements:

- Minimum length - 5 pages of text (not including graphs/figures/results)
- This paper should build substantially on the proposal, and lay out what work has been done up to this point, as well as an action plan for the spring semester.
- Must be sent to Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), by the last day of classes for the fall semester (typically the first week of December).

Senior Year - Spring Semester

Final Thesis Requirements:

In alignment with a typical advanced data analysis (ADA) project in the field of Statistics the minimum required length of the final thesis must be a minimum of 15 written pages, no more than 18 single-spaced pages, 12-point font. *This does **not** include figures.*

- Figures can be embedded within the text (so long as the overall text length requirement is met) but can also be provided as appendices after the main body of the text.
- Reports should be written in IMRaD format (Introduction, Methods, Results, and Discussion), where the "Introduction" can be a Background and Significance section followed by a Data section.
- All theses are due to the Undergraduate Program Director, Peter Freeman (pfreeman@andrew.cmu.edu), and Department Head, Rebecca Nugent (rnugent@andrew.cmu.edu), at the end of the 12th week of class in spring semester (roughly the first week of April).

Substitutions and Waivers

Many departments require Statistics & Data Science courses as part of their major or minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics & Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

However, the Statistics & Data Science department's Director of Undergraduate Studies can provide advice and information to the student's advisor about the viability of a proposed substitution. Students should make available as much information as possible concerning proposed substitutions. Students seeking waivers may be asked to demonstrate mastery of the material.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics & Data Science. In many of these cases, the student will need to take additional courses to satisfy the Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Statistics.

Statistics majors and minors seeking substitutions or waivers should speak to a departmental academic advisor.

Faculty

SIVARAMAN BALAKRISHNAN, Associate Professor - Ph.D., Carnegie Mellon; Carnegie Mellon, 2015-

ELI BEN-MICHAEL, Assistant Professor, Joint With Heinz College - Ph.D., University of California; Carnegie Mellon, 2022-

ZACHARY BRANSON, Assistant Teaching Professor - Ph.D., Harvard University; Carnegie Mellon, 2019-

DAVID CHOI, Associate Professor of Statistics and Information Systems - Ph.D., Stanford University; Carnegie Mellon, 2004-

ALEXANDRA CHOULDECHOVA, Estella Loomis McCandless Assistant Professor of Statistics and Public Policy - Ph.D., Stanford University; Carnegie Mellon, 2014-

REBECCA DOERGE, Dean of Mellon College of Science, Professor of Statistics - Ph.D., North Carolina State University; Carnegie Mellon, 2016-

PETER E. FREEMAN, Associate Teaching Professor; Director of Undergraduate Studies - Ph.D., University of Chicago; Carnegie Mellon, 2004-

CHRISTOPHER R. GENOVESE, Professor - Ph.D., University of California; Carnegie Mellon, 1994-

JOEL B. GREENHOUSE, Professor - Ph.D., University of Michigan; Carnegie Mellon, 1982-

AMELIA HAVILAND, Anna Loomis McCandless Professor of Statistics and Public Policy - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2003-

JIASHUN JIN, Professor - Ph.D., Stanford University; Carnegie Mellon, 2007-

ROBERT E. KASS, Maurice Falk Professor of Statistics & Computational Neuroscience - Ph.D., University of Chicago; Carnegie Mellon, 1981-

EDWARD KENNEDY, Associate Professor - Ph.D., University of Pennsylvania; Carnegie Mellon, 2016-

ARUN KUCHIBHOTLA, Assistant Professor - Ph.D., University of Pennsylvania; Carnegie Mellon, 2020-

MIKAEL KUUSELA, Assistant Professor - Ph.D., Ecole Polytechnique Federale de Lausanne; Carnegie Mellon, 2018-

ANN LEE, Professor, Co-Director of PhD program - Ph.D., Brown University; Carnegie Mellon, 2005-

JING LEI, Professor - Ph.D., University of California; Carnegie Mellon, 2011-

ROBIN MEJIA, Assistant Research Professor - Ph.D., University of California; Carnegie Mellon, 2018-

GONZALO E. MENA, Assistant Professor - Ph.D., Columbia University; Carnegie Mellon, 2023-

DANIEL NAGIN, Teresa and H. John Heinz III Professor of Public Policy - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1976-

MATEY NEYKOV, Associate Professor - Ph.D., Harvard University; Carnegie Mellon, 2017-

NYNKE NIEZINK, Assistant Professor - Ph.D., University of Groningen; Carnegie Mellon, 2017-

REBECCA NUGENT, Department Head, Stephen E. and Joyce Fienberg Professor of Statistics & Data Science - Ph.D., University of Washington; Carnegie Mellon, 2006-

AADITYA RAMDAS, Assistant Professor - Ph.D., Carnegie Mellon; Carnegie Mellon, 2018-

ALEX REINHART, Assistant Teaching Faculty - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018-

KATHRYN ROEDER, UPMC Professor of Statistics and Life Sciences - Ph.D., Pennsylvania State University; Carnegie Mellon, 1994-

CHAD M. SCHAFER, Professor - Ph.D., University of California, Berkeley; Carnegie Mellon, 2004-

TEDDY SEIDENFELD, Herbert A. Simon Professor of Philosophy and Statistics – Ph.D., Columbia University; Carnegie Mellon, 1985–

COSMA SHALIZI, Associate Professor – Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 2005–

WEIJING TANG, Assistant Professor – Ph.D., University of Michigan; Carnegie Mellon, 2023–

WILL TOWNES, Assistant Professor – Ph.D., Harvard University; Carnegie Mellon, 2022–

VALERIE VENTURA, Professor, Co-Director of PhD program – Ph.D., University of Oxford; Carnegie Mellon, 1997–

ISABELLA VERDINELLI, Professor in Residence – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991–

LARRY WASSERMAN, UPMC Professor of Statistics – Ph.D., University of Toronto; Carnegie Mellon, 1988–

RON YURKO, Assistant Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

Emeriti Faculty

GEORGE T. DUNCAN, Professor of Statistics and Public Policy – Ph.D., University of Minnesota; Carnegie Mellon, 1974–

WILLIAM F. EDDY, John C. Warner Professor of Statistics – Ph.D, Yale University; Carnegie Mellon, 1976–

BRIAN JUNKER, Professor – Ph.D., University of Illinois; Carnegie Mellon, 1990–

JOSEPH B. KADANE, Leonard J. Savage Professor of Statistics and Social Sciences – Ph.D., Stanford University; Carnegie Mellon, 1969–

JOHN P. LEHOCZKY, Thomas Lord Professor of Statistics – Ph.D, Stanford; Carnegie Mellon, 1969–

MARK J. SCHERVISH, Professor – Ph.D., University of Illinois; Carnegie Mellon, 1979–

DALENE STANGL, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

Special Faculty

PHILIPP BURCKHARDT, Director of e-Learning, Analytics, and Technology – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

F. SPENCER KOERNER, Lecturer – Ph.D., Carnegie Mellon; Carnegie Mellon, 2022–

JAMIE MCGOVERN, Director: Master of Statistical Practice Program – B.A., Rice University; Carnegie Mellon, 2020–

GORDON WEINBERG, Senior Lecturer – M.A., University of Pittsburgh; Carnegie Mellon, 2004–

Affiliated Faculty

ANTHONY BROCKWELL – Ph.D., Melbourne University; Carnegie Mellon, 1999–

BERNIE DEVLIN – Ph.D., Pennsylvania State University; Carnegie Mellon, 1994–

TAEYONG PARK, Assistant Teaching Professor – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2018–

ALESSANDRO RINALDO, Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 2005–

SAM VENTURA – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015–

Department of Statistics and Data Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

36-200 Reasoning with Data

All Semesters: 9 units

This course is an introduction to learning how to make statistical decisions and now to reason with data. The approach will emphasize the thinking-through of empirical problems from beginning to end and using statistical tools to look for evidence for/against explicit arguments/hypotheses. Types of data will include continuous and categorical variables, images, text, networks, and repeated measures over time. Applications will largely draw from interdisciplinary case studies spanning the humanities, social sciences, and related fields. Methodological topics will include basic exploratory data analysis, elementary probability, significance tests, and empirical research methods. There will be once-weekly computer lab for additional hands-on practice using an interactive software platform that allows student-driven inquiry.

36-202 Methods for Statistics & Data Science

All Semesters: 9 units

This course builds on the principles and methods of statistical reasoning developed in 36-200 (or its equivalents). The course covers simple and multiple regression, basic analysis of variance methods, logistic regression, and introduction to data mining including classification and clustering. Students will also learn the principles of overfitting, training vs testing, ensemble methods, variable selection, and bootstrapping. Course objectives include applying the basic principles and methods that underlie statistical practice and empirical research to real data sets and interdisciplinary problems. Learning the Data Analysis Pipeline is strongly emphasized through structured coding and data analysis projects. In addition to three lectures a week, students attend a computer lab once a week for "hands-on" practice of the material covered in lecture. There is no programming language pre-requisite. Students will learn the basics of R Markdown and related analytics tools.

Prerequisites: 36-207 or 36-247 or 70-207 or 36-200 or 36-220

36-204 Discovering the Data Universe

Intermittent: 3 units

Every day we wake up in the data universe, we use the information around us to make decisions. We are constantly evaluating and interpreting data from our environment, in everything from spreadsheets to Instagram posts. At the same time, our own personal data are being observed and recorded and #8212;through websites we visit online, our smart devices, and even our interactions with other students and faculty at CMU. Navigating this data universe requires knowledge of what data is and how to use it responsibly. For example, can a plant be a data set? Discovering the truth behind a piece of data, including who made it, what it looks like, and what we can learn from it, is a critical skill. Understanding data can be the difference between being able to distinguish truth from lies; and the key to identifying your data footprint and succeeding in research and in your career. In this course, we will explore the data universe from multiple angles and across several types of data. We will define, find, and analyze data, and most importantly, identify narratives within data to tell stories about the world around us. We will examine data using the following questions: How can we tell multiple stories from the same dataset? What biases can exist in data? And, who creates or decides what data matters enough to collect, preserve, and share? NOTE: There will be one in person and one virtual pre-recorded lecture each week.

36-217 Probability Theory and Random Processes

All Semesters: 9 units

This course provides an introduction to probability theory. It is designed for students in electrical and computer engineering. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, limit theorems, and an introduction to random processes. Some elementary ideas in spectral analysis and information theory will be given. A grade of C or better is required in order to use this course as a pre-requisite for 36-226 and 36-410. Not open to students who have received credit for 36-225, or 36-625.

Prerequisites: 21-256 or 21-122 or 21-123 or 21-259 or 21-112

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-218 Probability Theory for Computer Scientists

Fall and Spring: 9 units

Probability theory is the mathematical foundation for the study of both statistics and of random systems. This course is an intensive introduction to probability, from the foundations and mechanics to its application in statistical methods and modeling of random processes. Special topics and many examples are drawn from areas and problems that are of interest to computer scientists and that should prepare computer science students for the probabilistic and statistical ideas they encounter in downstream courses and research. A grade of C or better is required in order to use this course as a pre-requisite for 36-226, 36-326, and 36-410. If you hold a Statistics primary/additional major or minor you will be required to complete 36-226. For those who do not have a major or minor in Statistics, and receive at least a B in 36-218, you will be eligible to move directly onto 36-401.

Prerequisites: (21-112 and 21-111) or 21-120 or 21-256 or 21-259

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-219 Probability Theory and Random Processes

All Semesters: 9 units

This course provides an introduction to probability theory. It is designed for students in electrical and computer engineering. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, limit theorems, and an introduction to random processes. Some elementary ideas in spectral analysis and information theory will be given. A grade of C or better is required in order to use this course as a pre-requisite for 36-226 and 36-410.

Prerequisites: (21-112 and 21-111) or 21-120 or 21-256 or 21-259

36-220 Engineering Statistics and Quality Control

Fall and Spring: 9 units

This is a course in introductory statistics for engineers with emphasis on modern product improvement techniques. Besides exploratory data analysis, basic probability, distribution theory and statistical inference, special topics include experimental design, regression, control charts and acceptance sampling.

Prerequisites: 21-112 or 21-120

36-225 Introduction to Probability Theory

Fall and Summer: 9 units

This course is the first half of a year-long course which provides an introduction to probability and mathematical statistics for students in the data sciences. Topics include elementary probability theory, conditional probability and independence, random variables, distribution functions, joint and conditional distributions, law of large numbers, and the central limit theorem.

Prerequisites: (21-112 and 21-111) or 21-120 or 21-256 or 21-259

Course Website: <http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar> (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/>)

36-226 Introduction to Statistical Inference

Spring and Summer: 9 units

This course is the second half of a year long course in probability and mathematical statistics. Topics include maximum likelihood estimation, confidence intervals, hypothesis testing, and properties of estimators, such as unbiasedness and consistency. If time permits there will also be a discussion of linear regression and the analysis of variance. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-626.

Prerequisites: 21-325 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 36-217 Min. grade C or 15-259 Min. grade C

36-235 Probability and Statistical Inference I

Fall: 9 units

This class is the first half of a two-semester, calculus-based course sequence that introduces theoretical aspects of probability and statistical inference to students. The material in this course and in 36-236 (Probability and Statistical Inference II) is organized so as to provide repeated exposure to essential concepts: the courses cover specific probability distributions and their inferential applications one after another, starting with the normal distribution and continuing with the binomial and Poisson distributions, etc. Topics specifically covered in 36-235 include basic probability, random variables, univariate and multivariate distribution functions, point and interval estimation, hypothesis testing, and regression, with the discussion being supplemented with computer-based examples and exercises (e.g., visualization and simulation). Given its organization, the course is only appropriate for those taking the full two-semester sequence, and thus it is currently open only to statistics majors (primary, additional, dual) and minors. (Check with the statistics advisors for the exact declaration deadline.) Non-majors/minors requiring a probability course are directed to take 36-225 or one of its analogues. A grade of C or better in 36-235 is required in order to advance to 36-236 (or 36-226) and/or 36-410. This course is not open to students who have received credit for 36-217, 36-218, 36-219, or 36-700, or for 21-325 or 15-259.

Prerequisites: (21-111 and 21-112) or 21-256 or 21-259 or 21-120

36-236 Probability and Statistical Inference II

Spring: 9 units

This class is the second half of a two-semester, calculus-based course sequence that introduces theoretical aspects of probability and statistical inference to students. The material in this course and in 36-235 (Probability and Statistical Inference I) is organized so as to provide repeated exposure to essential concepts: the courses cover specific probability distributions and their inferential applications one after another, starting with the normal distribution and continuing with the binomial and Poisson distributions, etc. Topics specifically covered in 36-236 include the binomial and related distributions, the Poisson and related distributions, and the uniform distribution, and how they are used in point and interval estimation, hypothesis testing, and regression. Also covered in 36-236 are topics related to multivariate distributions: marginal and conditional distributions, covariance, and conditional distribution moments. All discussion is supplemented with computer-based examples and exercises (e.g., visualization and simulation). Given its organization, the course is only appropriate for those who first take 36-235, and thus it is currently open only to statistics majors (primary, additional, dual) and minors, as well as to CS majors using both 36-235 and 36-236 to complete their probability requirement. All others are directed to take 36-226. A grade of C or better in 36-236 is required in order to advance to 36-401.

Prerequisite: 36-235 Min. grade C

36-247 Statistics for Lab Sciences

Fall and Spring: 9 units

This course is a single-semester comprehensive introduction to statistical analysis of data for students in biology and chemistry. Topics include exploratory data analysis, elements of computer programming for statistics, basic concepts of probability, statistical inference, and curve fitting. In addition to three lectures, students attend a computer lab each week. Not open to students who have received credit for 36-200, 36-207/70-207, 36-220, or 36-226.

36-290 Introduction to Statistical Research Methodology

Fall: 9 units

This is a first course in statistical practice, targeted to first-semester sophomores. It is designed as a high-level introduction to the ways by which statisticians go about approaching and analyzing quantitative observational data, thus preparing students for future work in capstone classes. Students in the course are taught the basic concepts of statistical learning and #8212;inference vs. prediction, supervised vs. unsupervised learning, regression vs. classification, etc. and #8212;and will reinforce this knowledge by applying, e.g., linear regression, random forest, principal components analysis, and/or hierarchical clustering and more to datasets provided by the instructor. Students will also practice disseminating the results of their analyses via oral presentations and posters. Analyses will be carried out using the R programming language.

Prerequisites: 36-200 or 36-247 or 70-207 or 36-220 or 36-207

Course Website: <http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar> (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/>)

36-297 Early Undergraduate Research

Fall and Spring: 6 units

This course is designed to give early undergraduate students (those who have not yet taken 36-401) experience navigating real data science research problems. Small groups of students are matched with clients and do supervised research for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in, e.g., data acquisition and cleaning, exploratory data analysis, and basic statistical modeling; which skills are practiced is project-dependent. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Programming will be performed in R and/or Python; previous programming experience is not required.

36-300 Statistics & Data Science Internship

Summer: 3 units

The Department of Statistics and amp; Data Science considers experiential learning as an integral part of our program. One such option is through an internship. If a student has an internship, they don't have to register for this class unless they want it listed on their official transcripts. This process should be used by international students interested in Curricular Practical Training (CPT) and should also be authorized by the Office of International Education (OIE). More information regarding CPT is available on OIE's website. This course will be taken as Pass/Fail, and students will be charged tuition for 3 units. There is an approval process in order to register for this course. Please contact your advisor the Department of Statistics and amp; Data Science for more details.

36-301 Documenting Human Rights

Intermittent: 9 units

This course will teach students about the origins of modern human rights and the evolution of methods to document the extent to which these rights are being upheld or violated. The need to understand and document human rights issues is at the center of the most pressing current events. From threats to democracy and civil rights to work holding perpetrators of mass harm accountable in legal proceedings to efforts to quantify and advance economic, social, cultural, and environmental rights, making human rights violations visible is fundamental to achieving a more just world. We will begin with an overview of the history of human rights, the main philosophical and political debates in the field, and the most relevant organizations, institutions, and agreements. We will then delve into specific cases that highlight methodological opportunities and challenges, including: the identification of mass atrocity victims, the disappeared, and missing migrants; efforts to estimate civilian casualties in war; the documentation of police brutality and other human rights violations with smartphones; as well as the use of satellite imagery and drone footage for the documentation of genocide, environmental rights, and war crimes. We will critically assess the technical challenges that arise in each context and how the human rights and scientific communities have responded. After reviewing these cases, we will conclude by reflection on why the documentation of human rights actually matters and what happens to evidence once it is gathered. Students will then take what they've learned and do two multidisciplinary group projects, one involving the document of a rights violation in Western Pennsylvania and the other involving an international situation. Assignments include an essay, a data analysis assignment, and a group project that include a written component, quantitative and/or qualitative data analysis, and a presentation.

36-303 Sampling, Survey and Society

Spring: 9 units

This course will revolve around the role of sampling and sample surveys in the context of U.S. society and its institutions. We will examine the evolution of survey taking in the United States in the context of its economic, social and political uses. This will eventually lead to discussions about the accuracy and relevance of survey responses, especially in light of various kinds of nonsampling error. Students will be required to design, implement and analyze a survey sample.

Prerequisites: 36-208 or 36-202 or 36-309 or 36-220 or 36-226 or 36-326 or 70-208 or 36-236 or 36-218 Min. grade B

36-309 Experimental Design for Behavioral & Social Sciences

Fall and Summer: 9 units

This course focuses on the statistical aspects of the design and analysis stages of planned experiments. The design stage focuses on determining how experimental factors are allocated, the sample size necessary to achieve adequate statistical power, and how subjects/variables are measured. The analysis stage focuses on how data are collected and which statistical models are most appropriate to answer the research questions of interest. Although students will have to do some computer programming to implement these statistical techniques, the most important aspect of the course will be on interpreting analyses' results (e.g., whether a given analysis is appropriate, to what extent that analysis can answer research questions of interest, and the broader implications of an analysis within the context of the experiment). In addition to a weekly lecture, students will attend a computer lab once a week to get guidance and hands-on practice implementing statistical techniques we learn in class.

Prerequisites: 15-260 or 36-220 or 36-200 or 70-207 or 36-247 or 36-218 or 36-236 or 36-226 or 36-326

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-311 Statistical Analysis of Networks

Intermittent: 9 units

Networks are omnipresent. In this course, students will get an introduction to network science, mainly focusing on social network analysis. The course will start with some empirical background, and an overview of concepts used when measuring and describing networks. We will also discuss network visualization. Most traditional models cannot be applied straightforwardly to social network data, because of their complex dependence structure. We will discuss random graph models and statistical network models, that have been developed for the study of network structure and growth. We will also cover models of how networks impact individual behavior.

Prerequisite: 36-226

36-313 Statistics of Inequality and Discrimination

Intermittent: 9 units

Many social questions about inequality, injustice and unfairness are, in part, questions about evidence, data, and statistics. This class lays out the statistical methods which let us answer questions like "Does this employer discriminate against members of that group?", "Is this standardized test biased against that group?", "Is this decision-making algorithm biased, and what does that even mean?" and "Did this policy which was supposed to reduce this inequality actually help?" We will also look at inequality within groups, and at different ideas about how to explain inequalities between groups. The class will interweave discussion of concrete social issues with the relevant statistical concepts.

Prerequisite: 36-202

36-315 Statistical Graphics and Visualization

All Semesters: 9 units

Graphical displays of quantitative information take on many forms, and they help us understand data and statistical methods by (hopefully) clearly communicating arguments, results, and ideas. This course introduces students to the most common forms of graphical displays and their uses and misuses. Ideally, graphs are designed according to three key elements: The data structure, the graph's audience, and the designer's intended message. Students will learn how to create well-designed graphs and understand them from a statistical perspective. Furthermore, the course will consider complex data structures that are becoming increasingly common in data visualizations (temporal, spatial, and text data); we will discuss common ways to process these data that make them easy to visualize. As time permits, we may also consider more advanced graphical methods (e.g., interactive graphics and computer-generated animations). In addition to two weekly lectures, there will be weekly computer labs and homework assignments where students use R to visualize and analyze real datasets. Along the way, students also make monthly Piazza posts discussing the strengths and weaknesses of a graph they found online, thereby critiquing real graphical designs found in the wild. The course culminates in a group final project, where students make public-facing data visualizations and analyses for a real dataset. All assignments will be in R; although this is not a programming class, using programming-based statistical software like R is essential to create modern-day graphics, and this class will give you practice using this kind of software. Throughout, communication skills (usually written or visual, but sometimes spoken) will play an important role. Indeed, if it's true that "a picture speaks a thousand words," then ideally the one thousand words you are communicating with your graphics are statistically correct, clear, and compelling.

Prerequisites: 36-225 or 36-309 or 15-259 or 36-202 or 36-235 or 36-208 or 36-219 or 36-218 or 70-208 or 21-325

36-318 Introduction to Causal Inference

Intermittent: 9 units

Many social science and scientific inquiries can be framed as causal questions. Does a new cancer treatment cause a reduction in mortality? Do financial grants cause students to do better in college? Does a new public policy cause an increase in voter turnout? When tackling these questions, we frequently come across the phrase "correlation does not imply causation." If that's the case, then what does imply causation? In this course, we will discuss causal inference methods for measuring causal effects of different interventions (e.g., drug treatments, financial grants, and public policies). First, we will discuss how experiments and #8212;-where interventions are randomized among subjects and #8212;-can imply causation when an appropriate experimental design and statistical analysis is used. Then, we will discuss how observational studies and #8212;-where interventions are not randomized and #8212;-can also imply causation when approaches like propensity score methods, matching, and doubly robust estimation are employed. Finally, we will discuss instrumental variables and regression discontinuity designs and #8212;-which are frequently used in medicine and public policy for establishing causal inferences. Throughout we will use R to conduct causal analyses. A working knowledge of regression is encouraged, but regression will also be discussed and taught during much of the course.

Prerequisites: 36-219 Min. grade C or 36-225 Min. grade C or 36-235 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C

36-326 Mathematical Statistics (Honors)

Spring: 9 units

This course is a rigorous introduction to the mathematical theory of statistics. A good working knowledge of calculus and probability theory is required. Topics include maximum likelihood estimation, confidence intervals, hypothesis testing, Bayesian methods, and regression. A grade of C or better is required in order to advance to 36-401, 36-402 or any 36-46x course. Not open to students who have received credit for 36-625.

Prerequisites: 15-359 or 21-325 or 36-217 or 36-225 with a grade of A AND advisor approval. Students interested in the course should add themselves to the waitlist pending review.

Prerequisites: 15-359 Min. grade A or 36-225 Min. grade A or 21-325 Min. grade A or 36-217 Min. grade A or 36-218 Min. grade A

36-350 Statistical Computing

All Semesters: 9 units

Statistical Computing is a one-semester course that will introduce you to the fundamentals of computational data analysis, as carried out in the R programming language, and to the fundamentals of working with relational databases, such as SQLite. No previous knowledge of either is required.

Prerequisites: 36-235 Min. grade C or 15-259 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C

36-400 Introduction to Statistical Modeling and Learning

Spring: 9 units

This course is a high-level introduction both to fundamental concepts of probability and statistics and to the ways by which statisticians go about approaching and analyzing data. The course will cover data processing, exploratory data analysis, parameter estimation and hypothesis testing, clustering, and common regression and classification models. Students will carry out work using the R and Python programming languages. This course is open only to students completing the Data Science in Society minor.

36-401 Modern Regression

Fall: 9 units

This course is an introduction to the real world of statistics and data analysis using linear regression modeling. We will explore real data sets, examine various models for the data, assess the validity of their assumptions, and determine which conclusions we can make (if any). We will use the R programming language to implement our analyses and produce graphs and tables of results. Data analysis is a bit of an art; there may be several valid approaches. We will strongly emphasize the importance of critical thinking about the data and the question of interest. Our overall goal is to use data and a basic set of modeling tools to answer substantive questions, and to present the results in a scientific report.

Prerequisites: (36-236 Min. grade C or 36-326 Min. grade C or 36-226 Min. grade C or 36-218 Min. grade B) and (21-241 or 21-240 or 21-242)

36-402 Advanced Methods for Data Analysis

Spring: 9 units

This course introduces modern methods of data analysis, building on the theory and application of linear models from 36-401. Topics include nonlinear regression, nonparametric smoothing, density estimation, generalized linear and generalized additive models, simulation and predictive model-checking, cross-validation, bootstrap uncertainty estimation, multivariate methods including factor analysis and mixture models, and graphical models and causal inference. Students will analyze real-world data from a range of fields, coding small programs and writing reports.

Prerequisite: 36-401 Min. grade C

36-410 Introduction to Probability Modeling

Spring: 9 units

An introductory-level course in stochastic processes. Topics typically include Poisson processes, Markov chains, birth and death processes, random walks, recurrent events, and renewal theory. Examples are drawn from reliability theory, queuing theory, inventory theory, and various applications in the social and physical sciences.

Prerequisites: 36-225 or 36-217 or 21-325 or 36-235

36-460 Special Topics: Sports Analytics

Spring: 9 units

This course introduces students to fundamental topics in sports analytics and the relevant statistical methods for tackling problems in this growing area. The first half of the course will cover foundational topics in sports analytics including models for the expected value of game states, win probability, team ratings, and hierarchical models for player evaluation. The second half of the course will focus on spatio-temporal methods appropriate for modeling complex player-tracking data. The focus is on understanding the foundations of the considered methods and introducing software for implementation. Students will develop their own sports analytics project using techniques covered in the course for their final assessment.

Prerequisite: 36-401 Min. grade C

36-461 Special Topics: Statistical Methods in Epidemiology

Intermittent: 9 units

Epidemiology is concerned with understanding factors that cause, prevent, and reduce diseases by studying associations between disease outcomes and their suspected determinants in human populations. Epidemiologic research requires an understanding of statistical methods and design.

Epidemiologic data is typically discrete, i.e., data that arise whenever counts are made instead of measurements. In this course, methods for the analysis of categorical data are discussed with the purpose of learning how to apply them to data. The central statistical themes are building models, assessing fit and interpreting results. There is a special emphasis on generating and evaluating evidence from observational studies. Case studies and examples will be primarily from the public health sciences.

Prerequisite: 36-401 Min. grade C

Course Website: <http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar> (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/>)

36-462 Special Topics: Methods of Statistical Learning

Intermittent: 9 units

Data mining is the science of discovering patterns and learning structure in large data sets. Covered topics include information retrieval, clustering, dimension reduction, regression, classification, and decision trees.

Prerequisite: 36-401 Min. grade C

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-463 Special Topics: Multilevel and Hierarchical Models

Intermittent: 9 units

Multilevel and hierarchical models are among the most broadly applied "sophisticated" statistical models, especially in the social and biological sciences. They apply to situations in which the data "cluster" naturally into groups of units that are more related to each other than they are the rest of the data. In the first part of the course we will review linear and generalized linear models. In the second part we will see how to generalize these to multilevel and hierarchical models and relate them to other areas of statistics, and in the third part of the course we will learn how Bayesian statistical methods can help us to build, estimate and diagnose problems with these models using a variety of data sets and examples.

Prerequisite: 36-401 Min. grade C

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-464 Special Topics: Psychometrics: A Statistical Modeling Approach

Intermittent: 9 units

Much of the social, educational, policy, and professional worlds involve measuring the skills, abilities, attitudes, decision-making, etc. of people and #8212; from SAT's and GRE's for school, to 360-evaluations in business. This is the field of modern psychometrics, and it involves (at least) two kinds of craft: designing good sets of questions, and designing and fitting statistical models that extract the information we want from the responses to those questions. In this course we will touch on both kinds of craft, but we will concentrate on the second: what do statistical models for psychometric data look like, and how can we design, fit, and use them in practice? We will look at these models from a variety of statistical perspectives, but we will concentrate on the applied Bayesian point of view.

Prerequisite: 36-401 Min. grade C

Course Website: <http://www.stat.cmu.edu/academics/courselist> (<http://www.stat.cmu.edu/academics/courselist/>)

36-465 Special Topics: Conceptual Foundations of Statistical Learning

Intermittent: 9 units

This class is an introduction to the foundations of statistical learning theory, and its uses in designing and analyzing machine-learning systems. Statistical learning theory studies how to fit predictive models to training data, usually by solving an optimization problem, in such a way that the model will predict well, on average, on new data. The course will focus on the key concepts and theoretical tools, at a level accessible to students who have taken 36-401 and its pre-requisites. The course will also illustrate those concepts and tools by applying them to carefully selected kinds of machine learning systems (such as kernel machines). Students wanting exposure to a broad range of algorithms and applications would be better served by 36-462/662 ("Data Mining"). This class is for those who want a deeper understanding of the principles underlying all machine learning methods.

Prerequisite: 36-401 Min. grade C

36-466 Special Topics: Statistical Methods in Finance

Intermittent: 9 units

Financial econometrics is the interdisciplinary area where we use statistical methods and economic theory to address a wide variety of quantitative problems in finance. These include building financial models, testing financial economics theory, simulating financial systems, volatility estimation, risk management, capital asset pricing, derivative pricing, portfolio allocation, proprietary trading, portfolio and derivative hedging, and so on and so forth. Financial econometrics is an active field of integration of finance, economics, probability, statistics, and applied mathematics. Financial activities generate many new problems and products, economics provides useful theoretical foundation and guidance, and quantitative methods such as statistics, probability and applied mathematics are essential tools to solve quantitative problems in finance. Professionals in finance now routinely use sophisticated statistical techniques and modern computation power in portfolio management, proprietary trading, derivative pricing, financial consulting, securities regulation, and risk management.

Prerequisite: 36-401

36-467 Special Topics: Data over Space & Time

Intermittent: 9 units

This course is an introduction to the opportunities and challenges of analyzing data from processes unfolding over space and time. It will cover basic descriptive statistics for spatial and temporal patterns; linear methods for interpolating, extrapolating, and smoothing spatio-temporal data; basic nonlinear modeling; and statistical inference with dependent observations. Class work will combine practical exercises in R, a little mathematics on the underlying theory, and case studies analyzing real problems from various fields (economics, history, meteorology, ecology, etc.). Depending on available time and class interest, additional topics may include: statistics of Markov and hidden-Markov (state-space) models; statistics of point processes; simulation and simulation-based inference; agent-based modeling; dynamical systems theory.

Prerequisite: 36-401 Min. grade C

Course Website: <http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar> (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/depar/>)

36-468 Special Topics: Text Analysis

Intermittent: 9 units

The analysis of language is concerned with how variables relate to people (their gender, age, and location, for example), how variables relate to use (such as writing in different academic disciplines), and how variables change over time. While we are surrounded by data that might potentially shed light on many of these questions, working with real-world linguistic data can present some unique challenges in sampling, in the distribution of features, and in their high dimensionality. In this course, we work through some of these issues, paying particular attention to the aligning of the statistical questions we want to investigate with the choice of statistical models, as well as focusing on the interpretation of results. Analysis will be carried out in R and students will develop a suite of tools as they work through their course projects.

Prerequisites: 36-218 Min. grade B or 36-236 Min. grade C or 36-226 Min. grade C

36-469 Special Topics: Statistical Genomics and High Dimensional Inference

Intermittent: 9 units

The field of computational and statistical genomics focuses on developing and applying computationally efficient and statistically robust methods to sort through increasingly rich and massive genome wide data sets to identify complex genetic patterns, gene interactions, and disease associations. Because the genome is vast, analytical approaches require high dimensional statistical approaches such as multiple testing, dimension reduction techniques, regularization and high dimensional regression analysis, best linear unbiased prediction models, networks and graphical models. In this course, we will motivate these topics using data obtained from the human genetic and genomic literature. No prior knowledge in biology is required.

Prerequisite: 36-401 Min. grade C

36-471 Special Topics: Networks

Fall: 9 units

TBD

Prerequisite: 36-401 Min. grade C

36-490 Undergraduate Research

Fall and Spring: 9 units

This course is designed to give undergraduate students experience using statistics in real research problems. Small groups of students are matched with clients and do supervised research for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in approaching a research problem, critical thinking, and statistical analyses. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Client-facing and collaborative skills will be emphasized within a team setting, and students will learn leading practices for engaging stakeholders as well as gain a conceptual understanding of leading practices for project delivery.

36-493 Sports Analytics Capstone

Intermittent: 9 units

This course is designed to give undergraduate students experience applying statistics and data science methodology to research problems in sports analytics. Small groups of students will be matched with clients in the Carnegie Mellon Athletics Department and do supervised projects for a semester. Students will gain skills in approaching a real world problem, critical thinking, advanced statistical analysis, scientific writing, collaboration with clients, communicating results, and meeting expectations with respect to deliverables and timelines. The projects will change and rotate each semester. The course size is limited, and students will submit an application including their project preferences. Students with skill sets matching project needs will be given priority. We will also take into consideration whether or not a student has had a recent prior data science experience with the goal of providing experiences to a broad group of qualified students. Students do not need to be experts in sports analytics or have extensive knowledge in sports.

36-497 Corporate Capstone Project

Fall and Spring: 9 units

This course is designed to give undergraduate students experience applying statistics data science methodology to real industry projects. Small groups of students will be matched with industry clients and do supervised projects for a semester. From an academic perspective, the course presents an opportunity for students to gain skills in approaching a research problem, critical thinking, and statistical analyses. Additionally, the course will help students develop the professional skills necessary for successfully navigating team-based project delivery roles. Client-facing and collaborative skills will be emphasized within a team setting, and students will learn leading practices for engaging stakeholders as well as gain a conceptual understanding of leading practices for project delivery. The industry clients will change and rotate each semester; available projects will be advertised prior to the first week of class. The course size is limited; students apply the previous semester and placed on the course waitlist until project matching is performed. Students with skill sets matching project needs will be given priority. We will also take into consideration whether or not a student has had a recent prior corporate capstone experience with the goal of providing experiences to a broad group of qualified students. Note that there is no guarantee a waitlisted student will be matched to a project in any given semester.

36-498 Corporate Capstone II

Fall and Spring

This course allows students to continue work on projects begun as part of 36-497, Corporate Capstone Project. Enrollment is at the discretion of the external advisor for the 36-497 project and the Department of Statistics and Data Science.

36-700 Probability and Mathematical Statistics

Fall: 12 units

This is a one-semester course covering the basics of statistics. We will first provide a quick introduction to probability theory, and then cover fundamental topics in mathematical statistics such as point estimation, hypothesis testing, asymptotic theory, and Bayesian inference. If time permits, we will also cover more advanced and useful topics including nonparametric inference, regression and classification. Prerequisites: one- and two-variable calculus and matrix algebra. Graduate students in degree-seeking programs are given priority.

Dietrich College Interdisciplinary Majors

When addressing complex issues, we often rely on approaches that take advantage of a variety of relevant disciplines. The college houses the special category of "interdepartmental majors" for programs where this interdisciplinary approach is most pronounced and in which the varied disciplinary perspectives are most fully integrated. These majors are presented here separately, rather than as departmentally-based options, to reflect and underscore their sponsorship by more than one academic department and the unique features that follow from this structure.

Interdepartmental majors are administered by the academic department of the major's faculty advisor.

The Major in Economics and Politics

Politics and economics are deeply interconnected. Political institutions and decision-making impact economic growth, income distribution, and many other aspects of economic life. Both fiscal and monetary policies affect the economy, but these policies are often employed with political considerations in mind and can influence political activity. For example, while the United Nations is often thought of in purely political terms, the Security Council can and does impose sanctions on countries—an example of an economic policy used for political change.

The Economics and Politics major is offered jointly between the Undergraduate Economics Program (<https://www.cmu.edu/tepper/programs/undergraduate-economics/>) (UEP) and the Carnegie Mellon Institute for Security and Technology (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/instituteforpoliticsandstrategy/www.cmu.edu/cmist/>) (CMIST). Students are equal members of both academic units and receive advising from both units. The major will appeal to any student interested in the design, evaluation, and political implementation of policy. It will be especially attractive to students considering careers in politics, government agencies, political and business consulting, lobbying, or the law.

The BS in Economics and Politics is an interdisciplinary major. The major will develop the political context and underpinnings of economic policy making. It will explore how political institutions resolve the tradeoffs and disagreements associated with policymaking and how they can facilitate or impede desirable economic outcomes.

CMIST strengths lie in topics such as emerging technology, national security, and grand strategy. Economic policy is one facet of grand strategy, through which governments pursue domestic and international goals. It will enable students to understand economic statecraft from a broad perspective. This major will address key issues such as how multilateral economic institutions such as the IMF and World Bank use economic coercion. Whether coercion is successful or not depends not only on the levers of power but on also on variations in regime structures, alongside complex linkages in the international economy. For example, the viability of the "Euro Zone" depends on whether the political-economic agreements necessary to mitigate institutional weaknesses are politically feasible or destined to failure. In short, international economics affects everything from human rights practices to global compliance with climate change treaties.

Economics and Politics is available as both a primary and an additional major. The requirements are the same for both.

Curriculum

Students must earn a grade of "C" or better in all courses taken in the Department of Economics (73-xxx).

Mathematics

Students must complete all of the following courses.

| | | |
|-----------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| or 21-112 | Calculus II | |
| 21-256 | Multivariate Analysis | 9 |
| or 21-259 | Calculus in Three Dimensions | |

Foundations (36 units)

Students must complete all of the following courses.

| | | |
|-----------|--|---|
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-275 | Comparative Politics | 9 |

***Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102**

Core (63 units)

Students must complete all of the following courses.

| | | |
|--------|---------------------------------------|---|
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |
| 84-226 | International Relations | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-310 | International Political Economy | 9 |

Communication (9 units)

Students must complete one course from the following list.

| | | |
|--------|---|---|
| 73-270 | Professional Communication for Economists | 9 |
| 84-250 | Writing for Political Science and Policy | 9 |

Electives (27 units)

Majors are required to take 27 units (three courses) from the elective lists below. At least one course (9 units) must be taken from Economics (73-xxx) and at least one course (9 units) must be taken from the Carnegie Mellon Institute for Security and Technology (84-xxx). Students may complete electives through coursework in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (<https://www.cmu.edu/ips/cmuwsp/>).

Economics Electives

| | | |
|--------|---|----|
| 73-328 | Health Economics | 12 |
| 73-332 | Political Economy | 9 |
| 73-338 | Financial Crises and Risk | 9 |
| 73-352 | Public Economics | 9 |
| 73-353 | Financial Regulation in the Digital Age | 9 |
| 73-359 | Benefit-Cost Analysis | 9 |
| 73-365 | Firms, Market Structures, and Strategy | 9 |
| 73-421 | Emerging Markets | 9 |
| 73-427 | Sustainability, Energy, and Environmental Economics | 9 |

International Relations and Political Science Electives

| | | |
|--------|--|---|
| 84-200 | Security War Game Simulation | 6 |
| 84-252 | Briefing in the Policy World | 6 |
| 84-303 | International Human Rights | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-306 | Latin American Politics | 9 |
| 84-307 | Economic and Political History of Contemporary China | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-313 | International Organizations and Law <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-315 | Political Economy of International Migration | 9 |
| 84-316 | Political Economy of Transatlantic Partnership | 9 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |

| | | |
|----------------------|--|------|
| 84-329 | Asian Strategies | 6 |
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-334 | The History and Practice of Economic Statecraft <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-335 | US China Relations <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-337 | Biomedical Science Research, Policy, and Governance <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-339 | Seminar in Public Policy Research <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-348 | Advocacy, Policy and Practice <small>Taught in Washington, DC, through CMU/WSP</small> | 6 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-360 | CMU/WSP: Internship Seminar <small>Taught in Washington, DC, through CMU/WSP</small> | 12 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |
| 84-440 | Collaborative Research in Political Science | Var. |
| Additional Electives | | |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 88-323 | Policy in a Global Economy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-419 | International Negotiation | 9 |
| 88-444 | Public Policy and Regulations | 9 |

CAPSTONE (15-21 units)

Students must complete all of the following courses.

| | | |
|--------|--|---|
| 84-450 | Policy Seminar | 6 |
| 73-497 | Senior Project or Senior Honors Thesis | 9 |

Note: Students in the BS in Economics and Politics who complete a Dietrich or Tepper Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

DOUBLE-COUNTING RESTRICTION

A maximum of four courses may double count with another major or minor.

SAMPLE Four Year Plan

These sample curricula represent a plan for completing the requirements for the B.S. in Economics and Politics. Economics and Politics students are encouraged to spend a semester studying and interning in Washington, DC, through the CMU/WSP (<http://www.cmu.edu/ips/cmuwsp/>), and/or study abroad. The plan below demonstrates that a semester off-campus fits well into the curriculum. Students may declare the BS in Economics and Politics as early as the second semester of the freshman year and should consult frequently with the Economics and Politics advisors about their course of study. Please note that this is only a sample plan of study and not the only possible plan of study. The Economics and Politics major and Dietrich College General Education curricula provide a high degree of flexibility in sequencing and coursework. Double counting between the major and General Education requirements is unlimited. The plan below shows a very conservative view of double counting.

| First-Year | | Second-Year | |
|--|---------------------------------------|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 21-256 Multivariate Analysis | 73-230 Intermediate Microeconomics | 73-240 Intermediate Macroeconomics |
| 36-200 Reasoning with Data | 73-103 Principles of Macroeconomics | 73-265 Economics and Data Science | 73-274 Econometrics I |
| 73-102 Principles of Microeconomics | 84-275 Comparative Politics | 84-226 International Relations | Communication Course (84-250 or 73-270) |
| 84-104 Decision Processes in American Political Institutions | First-Year Writing | 84-266 Research Design for Political Science | General Education |
| Grand Challenge Seminar | Disciplinary Perspectives: Humanities | 84-310 International Political Economy | General Education |
| 99-101 Computing @ Carnegie Mellon | | | |

| Third-Year | | Fourth-Year | |
|-------------------------------|-------------------------|-------------------------------|-----------------------|
| Fall | Spring | Fall | Spring |
| General Education | CMU/WSP or Study Abroad | 73-497 Senior Project | 84-450 Policy Seminar |
| General Education | Explore | General Education | General Education |
| General Education | Explore | Economics & Politics Elective | Explore |
| General Education | Explore | Economics & Politics Elective | Explore |
| Economics & Politics Elective | Explore | Explore | Explore |

The Major in Economics and Statistics

Amanda Mitchell, *Statistics & Data Science Academic Program Manager*
 Stephen Pajewski, *Economics Senior Academic Advisor and Program Manager*

Statistics & Data Science Location: Baker Hall 129
 statadvising@andrew.cmu.edu (statadvising@stat.cmu.edu)

Economics Location: Tepper 2400
 econprog@andrew.cmu.edu

The B.S. in Economics and Statistics is jointly advised by the Department of Statistics and Data Science and the Undergraduate Economics Program.

The Major in Economics and Statistics provides an interdisciplinary course of study aimed at students with a strong interest in the empirical analysis of economic data. With joint curriculum from the Department of Statistics and Data Science and the Undergraduate Economics Program, the major provides students with a solid foundation in the theories and methods of both fields. Students in this major are trained to advance the understanding of economic issues through the analysis, synthesis and reporting of data using the advanced empirical research methods of statistics and econometrics. Graduates are well positioned for admission to competitive graduate programs, including those in statistics, economics and management, as well as for employment in positions requiring strong

analytic and conceptual skills - especially those in economics, finance, education, and public policy.

All economics courses counting towards an economics degree must be completed with a grade of "C" or higher.

Curriculum

The requirements for the B.S. in Economics and Statistics are the following:

1. MATHEMATICAL FOUNDATIONS (PREREQUISITES) 29-42 UNITS

Mathematics is the language in which statistical models are described and analyzed, so some experience with basic calculus and linear algebra is an important component for anyone pursuing a program of study in Economics and Statistics.

Calculus

Complete one of the two following sequences of mathematics courses at Carnegie Mellon, each of which provides sufficient preparation in calculus:

Sequence 1

| | | |
|--------|-------------|----|
| 21-111 | Calculus I | 10 |
| 21-112 | Calculus II | 10 |

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

Sequence 2

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
|--------|------------------------------------|----|

and *one* of the following:

| | | |
|--------|------------------------------|----|
| 21-256 | Multivariate Analysis | 9 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-268 | Multidimensional Calculus | 11 |

NOTES:

- Passing the MSC 21-120 assessment test is an acceptable alternative to completing 21-120.

Note: Taking/having credit for both 21-111 and 21-112 is equivalent to 21-120. The Mathematical Foundations total is then 48-49 units. The Economics and Statistics major would then total 201-211 units.

Linear Algebra

One of the following three courses:

| | | |
|--------|-------------------------------------|----|
| 21-240 | Matrix Algebra with Applications | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

Note: 21-241 and 21-242 are intended only for students with a very strong mathematical background.

II. Foundations 54 units

2. Economics Foundations 18 UNITS

Take one of the following courses:

| | | |
|--------|---|---|
| 73-102 | Principles of Microeconomics * | 9 |
| 73-104 | Principles of Microeconomics Accelerated ** | 9 |

Take the following course:

| | | |
|--------|------------------------------|---|
| 73-103 | Principles of Macroeconomics | 9 |
|--------|------------------------------|---|

*Students who place out of 73-102 based on the economics placement exam will receive a pre-req waiver for 73-102 and are waived from taking 73-102

**This course requires students to complete a 4 or 5 on the AP Microeconomics exam or qualifying score on the IB/Cambridge Exams. 73-104 will substitute for any 73-102 prerequisite requirement in other courses. 73-104 is a more rigorous introduction to microeconomics, is taught at a faster pace than 73-102, and dives a bit deeper into key topics. It is designed for students who have prior knowledge to fundamental economic concepts through AP/IB/Cambridge coursework. Enrollment in 73-104 requires special permission. Students who wish

to take this course should add themselves to the 73-104 waitlist once registration opens. The Tepper School will verify the advancement placement scores and will enroll students in 73-104

3. Statistical Foundations 36 UNITS

DATA ANALYSIS

Data analysis is the art and science of extracting insight from data. The art lies in knowing which displays or techniques will reveal the most interesting features of a complicated data set. The science lies in understanding the various techniques and the assumptions on which they rely. Both aspects require practice to master.

The Beginning Data Analysis courses give a hands-on introduction to the art and science of data analysis. The courses cover similar topics but differ slightly in the examples they emphasize. 36-200 draws examples from many fields and satisfy the DC College Core Requirement in Statistical Reasoning. This course is therefore recommended for students in the college. (Note: a score of 5 on the Advanced Placement [AP] Exam in Statistics may be used to waive this requirement). 36-220 emphasizes examples in engineering.

The Intermediate Data Analysis courses build on the principles and methods covered in the introductory course, and more fully explore specific types of data analysis methods in more depth.

The Advanced Data Analysis courses draw on students' previous experience with data analysis and understanding of statistical theory to develop advanced, more sophisticated methods. These core courses involve extensive analysis of real data with emphasis on developing the oral and writing skills needed for communicating results.

Sequence 1 (For students beginning their freshman or sophomore year)

Beginning*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-200 | Reasoning with Data * | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |

*A score of 5 on the Advanced Placement (AP) Exam in Statistics may be used to waive this requirement. 36-220 emphasizes examples in engineering and Architecture.

Note: Students who enter the program with 36-235 or 36-236 should discuss options with an advisor. Any 36-300 or 36-400 level course in Data Analysis that does not satisfy any other requirement for the Economics and Statistics Major may be counted as a Statistical Elective.

Intermediate*

Choose *one* of the following courses:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science ** | 9 |
| 36-290 | Introduction to Statistical Research Methodology | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |

* Or extra data analysis course in Statistics

** Must take prior to 36-401 Modern Regression, if not, an additional Advanced Statistics Elective is required.

Advanced Statistics Elective

Choose *two* of the following courses:

| | | |
|--------|--|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |

| | | |
|--------|---|---|
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Sequence 2 (For students beginning later in their college career)**Advanced Statistics Electives**Choose *three* of the following courses:

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-460 | Special Topics: Sports Analytics | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 36-465 | Special Topics: Conceptual Foundations of Statistical Learning | 9 |
| 36-466 | Special Topics: Statistical Methods in Finance | 9 |
| 36-467 | Special Topics: Data over Space & Time | 9 |
| 36-468 | Special Topics: Text Analysis | 9 |
| 36-469 | Special Topics: Statistical Genomics and High Dimensional Inference | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

**All Special Topics are not offered every semester, and new Special Topics are regularly added. See section 5 for details.

III. Disciplinary Core**136-139 units****1. Economics Core 45 UNITS**

| | | |
|--------|---|---|
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 73-270 | Professional Communication for Economists | 9 |
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |
| 73-374 | Econometrics II | 9 |

2. Statistics Core 36 UNITS

Take one of the following courses:

| | | |
|--------|---|---|
| 36-235 | Probability and Statistical Inference I ^{##} | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

Take one of the following courses:

| | | |
|--------|--|---|
| 36-236 | Probability and Statistical Inference II ^{**} | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-326 | Mathematical Statistics (Honors) | 9 |

Take both of the following courses:

| | | |
|--------|------------------------------------|---|
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

*In order meet the prerequisite requirements for the major, a grade of C or better is required in 36-235 (or equivalents), 36-236 or 36-326 and 36-401.

#It is possible to substitute 36-218, 36-219, 36-225 or 21-325 for 36-235. 36-235 is the standard introduction to probability, 36-219 is tailored for engineers and computer scientists, 36-218 is a more mathematically rigorous class for Computer Science students and more mathematically advanced Statistics students (Statistics students need advisor approval to enroll), and 21-325 is a rigorous Probability Theory course offered by the Department of Mathematics.

**It is possible to substitute 36-226 or 36-326 for 36-236. 36-236 is the standard introduction to statistical inference.

Please note that students who complete 36-235 are expected to take 36-236 to fulfill their theory requirements. Students who choose to take 36-225 instead will be required to take 36-226 afterward, they will not be eligible to take 36-236.

3. Statistical Computing 19-21 UNITS

Take one of the following two courses:

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Complete the following course:

| | | |
|--------|-----------------------|---|
| 36-350 | Statistical Computing | 9 |
|--------|-----------------------|---|

4. Advanced Electives 36 units

Students must take two advanced Economics elective courses (numbered 73-300 through 73-495, excluding 73-374) and two (or three - depending on previous coursework, see Section 3) advanced Statistics elective courses (numbered 36-303, 36-311, 36-313, 36-315, 36-318, 36-46x, 36-490, 36-493 or 36-497).

Total number of units for the major 219-235 Units

Total number of units for the degree 360 Units

Professional Development

While not required, students are strongly encouraged to take advantage of professional development opportunities and/or coursework. One option is , a fall-only course that provides information about careers in Economics, job search strategies, and research opportunities. The Department of Statistics and Data Science also offers a series of workshops pertaining to resume preparation, graduate school applications, careers in the field, among other topics. Students should also take advantage of the Career and Professional Development Center.

Additional Major in Economics and Statistics

Students who elect Economics and Statistics as an additional major must fulfill all Economics and Statistics degree requirements. Majors in many other programs would naturally complement an Economics and Statistics Major, including Tepper's undergraduate business program, Social and Decision Sciences, Policy and Management, and Psychology.

With respect to double-counting courses, it is departmental policy that students must have at least six courses [three Economics (73-xxx) and three Statistics (36-xxx)] that do *not* count for their primary major. If students do not have at least three ECON and three STA classes, they will need to take additional advanced data analysis or economics electives, depending on where the double-counting issue is.

Students are advised to begin planning their curriculum (with appropriate advisors) as soon as possible. This is particularly true if the other major has a complex set of requirements and prerequisites or when many of the other major's requirements overlap with the requirements for a Major in Economics and Statistics.

Substitutions and Waivers

Many departments require Statistics courses as part of their Major or Minor programs. Students seeking transfer credit for those requirements from substitute courses (at Carnegie Mellon or elsewhere) should seek permission from their advisor in the department setting the requirement. The final authority in such decisions rests there. The Department of Statistics and Data Science does not provide approval or permission for substitution or waiver of another department's requirements.

If a waiver or substitution is made in the home department, it is not automatically approved in the Department of Statistics and Data Science. In many of these cases, the student will need to take additional courses to satisfy the Economics and Statistics major requirements. Students should discuss this with a Statistics advisor when deciding whether to add an additional major in Economics and Statistics.

Sample Program

The following sample program illustrates one way to satisfy the requirements of the Economics and Statistics Major. Keep in mind that the

program is flexible and can support other possible schedules (see footnotes below the schedule).

| First-Year | | Second-Year | |
|---|--|--|---|
| Fall | Spring | Fall | Spring |
| 21-120 Differential and Integral Calculus | 36-202 Methods for Statistics & Data Science | 36-235 Probability and Statistical Inference I | 36-236 Probability and Statistical Inference II |
| 36-200 Reasoning with Data | 21-256 Multivariate Analysis | 73-230 Intermediate Microeconomics | 21-240 Matrix Algebra with Applications |
| 73-102 Principles of Microeconomics | 73-103 Principles of Macroeconomics | | 73-240 Intermediate Macroeconomics |
| 15-110 Principles of Computing | ----- | 73-265 Economics and Data Science | 73-274 Econometrics I |
| | ----- | ----- | ----- |

| Third-Year | | Fourth-Year | |
|------------------------------|--|--|--|
| Fall | Spring | Fall | Spring |
| 36-350 Statistical Computing | 36-402 Advanced Methods for Data Analysis | 36-3xx or 36-4xx Advanced Data Analysis Elective | 36-3xx or 36-4xx Advanced Data Analysis Elective |
| 36-401 Modern Regression | 73-270 Professional Communication for Economists | Economics Elective | Economics Elective |
| 73-374 Econometrics II | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |
| ----- | ----- | ----- | ----- |

*In each semester, ----- represents other courses (not related to the major) which are needed in order to complete the 360 units that the degree requires.

Prospective PhD students are advised to add 21-127 fall of sophomore year, replace 21-240 with 21-241, add 21-260 in spring of junior year and 21-355 in fall of senior year.

The Major in Ethics, History, and Public Policy

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The B.A./B.S. in Ethics, History, and Public Policy (EHPP) is an interdepartmental major offered jointly by the Departments of History and Philosophy.

Preparing students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Curriculum

Students seeking a primary major in Ethics, History, and Public Policy may elect to receive either a Bachelor of Arts or a Bachelor of Science degree (additional requirements apply; see below). Basic requirements include 120 units encompassing 45 units in History, 45 units in Philosophy, 18 units in Law and Social Science, and a 12-unit EHPP Capstone Course. This program may also be taken as an additional (i.e., second) major. All courses toward

the major must be taken for a letter grade and must be passed with a grade of "C" or better. Students can double count any course for the major with another major or minor, with the exception of Social and Political History, for which a student can double count a maximum of two courses.

I. Foundation Courses in History and Philosophy 18 units

Choose one of the following two courses:

| | | |
|--------|---|---|
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |

Choose one of the following two courses:

| | | |
|--------|------------------------|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-330 | Ethical Theory | 9 |

II. Ethics and Policy Core 36 units

Choose four of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

| | | |
|--------|---|---|
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

III. History and Policy Core 36 units

Choose four of the courses below:

| | | |
|--------|--|---|
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-204 | American Environmental History | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-234 | Technology and Society | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

IV. Foundation Courses in Law and Social Science 18 units

Choose two of the courses below:

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 70-332 | Business, Society and Ethics | 9 |
| 73-102 | Principles of Microeconomics | 9 |

| | | |
|--------|---|---|
| 73-103 | Principles of Macroeconomics | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

EHPP students will also be able to complete the Foundations of Law and Social Science category by participating in the Washington Semester Program. Students are encouraged to pursue additional policy-relevant courses in law and social science, along lines consistent with their career ambitions.

V. EHPP Capstone Course 12 units

In Fall semester of senior year, EHPP students will participate in an interdisciplinary capstone course that asks students to integrate their studies in Ethics and History by addressing a policy topic of contemporary national urgency (e.g., climate change, immigration, infrastructure, abortion, hate speech, reparations, law enforcement and policing, charter schools, affirmative action, vaccination, taxation, voting rights, global justice). The Departments of History and Philosophy will alternate teaching the EHPP Capstone Course.

| | | |
|--------|-------------------------------------|----|
| 79-449 | EHPP Capstone Course [cross-listed] | 12 |
| 80-449 | EHPP Capstone Course [cross-listed] | 12 |

VI. Bachelor of Science Option

Students may elect to earn a Bachelor of Science rather than a Bachelor of Arts degree by completing two courses from the list below, or by petitioning the Director of EHPP to accept equivalent courses as substitutions.

| | | |
|-----------|--|----|
| 21-257 | Models and Methods for Optimization | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 70-208 | Regression Analysis | |
| 36-303 | Sampling, Survey and Society | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 70-257 | Optimization for Business | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-251 | Empirical Research Methods | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Additional Major

The B.A./B.S. in Ethics, History, and Public Policy may be scheduled as an additional major in consultation with the Director of Ethics, History, and Public Policy.

Ethics, History, and Public Policy Sample Curriculum

| Third-Year | | Fourth-Year | |
|----------------------------------|---|--------------------------------|--------------------------------|
| Fall | Spring | Fall | Spring |
| Foundations Course in History | Foundations Course in Law and Social Sciences | EHPP Capstone Course | Ethics and Policy Core Course |
| Foundations Course in Philosophy | Foundations Course in Law and Social Sciences | Ethics and Policy Core Course | History and Policy Core Course |
| Ethics and Policy Core Course | Ethics and Policy Core Course | History and Policy Core Course | Third Course (open) |
| History and Policy Core Course | History and Policy Core Course | Fourth Course (open) | Fourth Course (open) |
| Fifth Course Open | Fifth Course (open) | Fifth Course (open) | Fifth Course (open) |

The above sample program is presented as a two-year (junior-senior year) plan for completing EHPP major requirements. Its purpose is to show that this program can be completed in as few as two years; not that it must be.

Students may enter the EHPP major, and begin major course requirements, as early as they wish. Students should consult their advisor when planning their program.

The Major in Information Systems

Joseph S. Mertz, Jr., *Faculty Program Director*
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Artificial intelligence. Machine learning. Deep learning. Big data. Social networks. Neural networks. Robotics. Automated voice assistants. Blockchain. Driverless vehicles. Web design. Carnegie Mellon University's Information Systems (IS) program (p. 409) will help you do just that. At CMU, Information Systems is a joint degree program between Heinz College and Dietrich College of Humanities and Social Sciences and is strongly technical, drawing from Carnegie Mellon's leadership in computer science, human-centered design, business management, and software engineering. It is deeply rooted in the humanities and social sciences, allowing students the lifelong benefits of a rich liberal arts education. And it provides pathways for students to find their own Information Systems niche through advanced study and exploration with leading researchers.

In addition to General Education Requirements and basic prerequisites in Mathematics and Computer Science, The IS program curriculum includes a broad grounding in humanities and social sciences to promote critical thinking, and interdisciplinary problem-solving, an Information Systems Core to provide business-facing skills needed to design and build effective real-world systems solutions, an Information Systems Breadth focused on professional communications, quantitative analysis, and how technology functions in society, and a concentration that gives you the flexibility and agency to gain expertise in a supporting area and define your own niche in IS.

The IS major is the perfect place for you if you are passionate about using technology for positive gains across society, both economic and humanistic.

For full program information, go to The Major in Information Systems (p. 409).

The Major in Linguistics

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Linguistics is the scientific study of human language. The central goal of the Linguistics Major is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Major is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning.

The **Core courses** cover the principal domains of linguistic analysis: phonetics and phonology, syntax and meaning.

Students then move on to the **Extended Core**, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. These courses are supplemented by a wide-ranging set of electives including linguistically relevant courses taught in other departments.

Primary majors complete their course of study with a Senior Thesis, a semester-long research project carried out independently with one-on-one guidance from a member of the linguistics faculty.

Curriculum

The Linguistics **primary major** requires a total of 12 courses plus a senior thesis. The Linguistics **additional major** requires a total of 13 courses (senior thesis not required). This includes 2 semesters of sequential language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor.

Linguistics Core (36 units)

Complete the following requirements.

| | | |
|-----------|---------------------------|---|
| 80-180 | Nature of Language | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-280 | Linguistic Analysis | 9 |
| or 80-285 | Natural Language Syntax | |
| 80-381 | Meaning in Language | 9 |
| or 80-383 | Language in Use | |

Extended Core (27 units)

Choose three courses (27 units) from Extended Core and/or additional courses from Linguistics Core.

| | | |
|--------|---|---|
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |

LANGUAGE REQUIREMENT

Students must successfully complete 2 semesters of foreign language study in a single language (e.g. 100 & 200 level).

Electives

Primary majors choose **three** additional electives (27 or more units). Additional majors choose **four** additional electives (36 or more units). Primary majors: see *thesis requirement* below.

These Electives can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which is approved by the Academic Program Manager as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The Academic Program Manager will provide students with a list of possible electives each semester, and will assist students in selecting electives which are consistent with their goals and interests.

| | | |
|---------------------------------|--|----|
| Philosophy | | |
| 80-380 | Philosophy of Language | 9 |
| 80-484 | Language and Thought | 9 |
| English | | |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-325 | Intertextuality | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-386 | Language & Culture | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| Modern Languages | | |
| 82-239 | Crazy Linguistically Rich Asian Languages | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |
| 82-305 | French in its Social Contexts | 9 |
| 82-334 | Structure of Chinese | 9 |
| 82-585 | Topics in Second Language Acquisition | 9 |
| 82-373 | Structure of the Japanese Language | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| Psychology | | |
| 85-354 | Infant Language Development | 9 |
| 85-421 | Language and Thought | 9 |
| Language Technologies Institute | | |
| 11-411 | Natural Language Processing | 12 |
| 11-423 | ConLanging: Lrng. Ling. & Lang Tech via Constr. Artif. Lang. | 12 |
| 11-492 | Speech Processing | 12 |
| 11-422 | Grammar Formalisims | 12 |

Note: all 11-xxx courses have significant Computer Science prerequisites. Interested students should check with the course instructor and with the Linguistics Academic Program Manager before registering.

Statistics and Data Science

36-468 Special Topics: Text Analysis

9

SENIOR THESIS [PRIMARY MAJORS ONLY]

Primary majors must complete a senior thesis (a workload equivalent to a 12-unit course) 80-595 Senior Thesis. Topics must be approved by an advisor, who will work with the student and guide the thesis project. Students are responsible for identifying their topic and securing their thesis advisor. Students should work with the Academic Program Manager of the major to begin the process of identifying their thesis topic and advisor during the fall of their senior year at the latest. Students will be required to submit a written proposal of their thesis project, signed by their thesis faculty advisor, before the end of the semester preceding that in which the thesis research will be conducted..

Additional Major in Linguistics

The Linguistics additional major requires a total of 13 courses. This includes 2 semesters of language study for all majors. At least three courses (not including specific language courses) must be at the 300-level or higher. Additional majors are not required to write a thesis but must take four electives (36 or more units). All courses counted towards the major must be taken for a letter grade and passed with a grade of "C" or above. Students may double count any course for the major simultaneously with another major or minor. If you are interested in obtaining an additional major in Linguistics, please reach out to the Academic Program Manager, Philosophy Department.

The Major in Psychology and Biological Sciences

This unified major is intended to reflect the interdisciplinary nature of our current research in the fields of psychology and biology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences. Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students entering from the Mellon College of Sciences receive a Bachelor of Science in Biological Sciences and Psychology.

Pre-Major Requirements

The unified major specifies particular pre-major requirements in the areas of mathematical sciences and statistics, natural science, and computational reasoning. Particular courses are specified in these areas because they are prerequisites for courses required in the major and therefore they are the most efficient way to complete the general education requirements for either Dietrich College or SHS. All other general education categories can be filled in any way that satisfies the requirements of the student's college or of the SHS program.

The major in Psychology and Biological Sciences is offered only as a B.S. degree. Full curriculum requirements can be viewed under the Department of Psychology (p. 502) section of the Catalog.

Student-Defined Major Program

Joseph E. Devine, *Director and Associate Dean for Undergraduate Studies*
 Location: Baker Hall 154F
 jd0x@andrew.cmu.edu
www.cmu.edu/dietrich/academics/degrees-majors-minors/student-defined-majors.html (<https://www.cmu.edu/dietrich/academics/degrees-majors-minors/student-defined-majors.html>)

For Dietrich College students whose educational goals cannot be as adequately served by the curricula of existing majors, the college offers the opportunity to self-define a major. The procedure for establishing such a major centers on a written proposal, submitted to the Dietrich College Dean's Office. This proposal consists of two parts:

Major Description and Rationale

A description of the components of the proposed program of study; a presentation of the objectives of the program of study, how it represents a coherent and (given available faculty, courses, and other resources) viable course of study, and the reason(s) why these objectives cannot be accomplished within one or more of the college's existing majors.

Curriculum

Presentation of a complete outline of all courses that will comprise the requirements for the major. These courses should be categorized in

two ways: first, according to that component of the major program to which each belongs (e.g., mathematical prerequisites; research methods; theoretical perspectives; etc.); and second, a semester-by-semester outline that indicates when each course is to be taken (or, for any already taken, when taken and grade received). In addition to courses taken at Carnegie Mellon, the major's curriculum may include courses taken (or to be taken) at other schools, related projects or internships, or programs of study abroad. The minimum requirements for graduation is, as with all majors in the college, 360 units of credit and completion of the Dietrich College general education program.

Proposals and curricula are evaluated for clarity of focus, coherence and depth in related areas, and viability. Proposals should generally be developed no later than the sophomore year, and approved majors begin their program generally no later than the junior year.

The student-defined option is also possible to propose as an additional major or minor. These options extend to undergraduates from all Carnegie Mellon colleges.

Dietrich College Interdisciplinary Minors

Dietrich College interdepartmental minors are programs whose content and components span two or more academic departments to form coherent patterns of study.

A number of interdepartmental minors are offered by Dietrich College and are, in general, available to all Carnegie Mellon undergraduate students. As well, there are numerous other minors offered by other colleges in the university that are generally available to Dietrich College students. The full list of minors available to Carnegie Mellon students is located in the catalog index under "Minors."

Completion of the requirements for any of these minors is noted on the final transcript.

To declare a Dietrich College interdepartmental minor, students should contact the college's Academic Advisory Center (AAC) and the faculty advisor for that minor.

To discuss the possibility of declaring a non-Dietrich College minor, contact the advisor listed for the minor in question.

In general, unless noted, no course taken to fulfill requirements for these interdepartmental minors may apply toward any other program's requirements.

The Minor in African and African American Studies

Professor Edda L. Fields-Black, *Faculty Advisor*, History Department
Location: Baker Hall 231B, 412-268-8012
fieldsblack@andrew.cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

Mission

The African and African American Studies minor introduces students to several large regions of the world: sub-Saharan Africa, the Americas, and the Caribbean. Broad geographic coverage and a comparative framework encourage students to make connections between Africa and the African Diaspora, as well as among different Diasporan communities. The minor offers undergraduates the opportunity to undertake an empirical and theoretical examination of the cultural, political, social, and historical experiences of Africans and people of African descent.

This unique transnational minor brings together several departments and colleges within the university and allows students to develop analytical skills particular to the arts, humanities, social sciences, public policy, and management. The African and African American Studies minor allow students a considerable degree of freedom in their choice of electives and independent research projects, including opportunities to study and conduct research in a relevant foreign language.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Requirements

- The minor is composed of 54 units - two core courses and four elective courses.
- The elective courses must include one course that requires a research paper or project.
- Students may take an additional two core courses as electives, but not more than four total courses.
- Students must take courses in at least two of the four regions (African, African American, Latin American, and the Caribbean) between their core and elective courses.

Core Courses

18 units

Choose two from the History and/or English Department courses listed below:

| | | |
|---------|---|---|
| African | | |
| 79-226 | African History: Earliest Times to 1780 | 9 |

| | | |
|--------|--|---|
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
|--------|--|---|

African American

| | | |
|--------|---|---|
| 76-232 | Introduction to Black Literature | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |

Elective Courses

36 units

African

| | | |
|--------|---|---|
| 79-225 | West African History in Film | 9 |
| 79-237 | Comparative Slavery * | 9 |
| 79-290 | The Slave Passage: From West Africa to the Americas | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 82-303 | French & Francophone Cultures | 9 |
| 82-304 | French & Francophone Sociolinguistics ** | 9 |

African American

| | | |
|--------|--|---|
| 57-480 | History of Black American Music | 6 |
| 76-238 | What Was the Hip-Hop Generation? | 9 |
| 76-333 | Race and Controversy in the Arts | 9 |
| 76-407 | Topics in Literary & Cultural Studies : There Are Black People in the Future | 9 |
| 79-237 | Comparative Slavery * | 9 |
| 79-247 | African Americans, Imprisonment, and the Carceral State | 9 |
| 79-252 | "Harriet": Harriet Tubman, Slavery, and the Underground Railroad | 6 |
| 79-304 | African Americans in Pittsburgh | 6 |
| 79-333 | African Americans, Race, and the Fight for Reparations | 9 |
| 79-371 | African American Urban History | 9 |

Caribbean

| | | |
|--------|---|---|
| 79-237 | Comparative Slavery * | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 82-303 | French & Francophone Cultures | 9 |
| 82-304 | French & Francophone Sociolinguistics ** | 9 |

Latin American

| | | |
|--------|--|---|
| 79-317 | Art, Anthropology, and Empire | 9 |
| 82-343 | Latin America Language and Culture | 9 |
| 82-451 | Studies in Latin American Literature and Culture | 9 |

Notes:

* Denotes courses that require a research paper/project.

** Denotes courses taught in a foreign language

The Minor in Film and Media Studies

Laura E. Donaldson, *Academic Advisor*
Jeffrey Hinkelman, *Faculty Advisor*

Location: Department of English, Baker Hall 259

Film and the electronic media are a crucial part of contemporary culture and society; they constitute an important tool for understanding social arrangements, historical changes, and play an increasingly important role in the development of aesthetic and cultural theory. The Dietrich College minor in Film and Media Studies offers students the opportunity to engage with film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, as well as the development of a complex blend of creative, professional, and technical competencies.

A maximum of two courses may double count with other programs.

The courses listed below are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. A faculty advisor for the minor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

Required Introductory Course 9 units

| | | |
|--------|---|---|
| 76-239 | Introduction to Film Studies (prerequisite for 76-439) | 9 |
|--------|---|---|

Required Intermediate Course 9 units

| | | |
|--------|------------------------------------|---|
| 76-310 | Advanced Studies in Film and Media | 9 |
|--------|------------------------------------|---|

Film and Media Electives 27 units

Complete a minimum of 27 units of course work at the 200-level or above when the primary topic is film and media. Courses may include, but are not limited to, the following:

| | | |
|--------|---|------|
| 54-191 | Acting for Non-Majors | 9 |
| 76-243 | Introduction to Television | 9 |
| 76-259 | Film History | 9 |
| 76-269 | Introduction to Screenwriting | 9 |
| 76-292 | Introduction to Film Production | 9 |
| 76-295 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 76-312 | Crime and Justice in American Film | 9 |
| 76-313 | Creative Visual Storytelling in Film Production | 9 |
| 76-339 | Topics in Film and Media * | 9 |
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-367 | Fact Into Film: Translating History into Cinema | 9 |
| 76-374 | Mediated Narrative | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-449 | Race and Media | 9 |
| 76-454 | Rise of the Blockbuster | 9 |
| 76-456 | Independent Study in Film & Media Studies (requires prior approval) | Var. |
| 76-469 | Screenwriting Workshop | 9 |
| 79-220 | Screening Mexico: Mexican Cinema, 1898 to Present | 6 |
| 79-306 | Fact into Film: Translating History into Cinema | 9 |
| 79-308 | Crime and Justice in American Film | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| 79-319 | India Through Film | 6 |
| 79-340 | Juvenile Delinquency & Film: From "Boyz N the Hood"(1991) to "The Wire"(2002-08) | 6 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-296 | World War I - the View from Paris & St. Petersburg | 6 |
| 82-362 | Italian Language and Culture II (if significant portion of course pertains to film) | 9 |
| 82-253 | Korean Culture Through Film | 9 |
| 82-428 | History of German Film | 9 |
| 82-456 | Topics in Hispanic Studies (if significant portion of course pertains to film) | 9 |
| 82-533 | Cultural Topics in Chinese Studies (if significant portion of course pertains to film) | 6 |

* May be taken up to three times and counted for additional credit toward Film and Media Electives if topics differ.

Students should consult with a faculty advisor for the minor regarding courses not listed above.

400-level Film and Media Course 9 units

Complete one 400-level course from the Department of English that concentrates on film/media directly or that uses it as a tool of social or cultural analysis.

| | | |
|--------|--|------|
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-454 | Rise of the Blockbuster | 9 |
| 76-449 | Race and Media | 9 |
| 76-456 | Independent Study in Film & Media Studies (requires prior approval) | Var. |
| 76-467 | Crime Fiction and Film | 9 |
| 76-469 | Screenwriting Workshop | 9 |

The Minor in Gender Studies

Lisa Tetrault, *Professor of History and Faculty Advisor*
tetrault@andrew.cmu.edu
Location: English Department, Baker Hall 259

Gender studies is an interdisciplinary field that investigates how gender is embedded in social, cultural, and political relationships. It understands gender as a category of power that intersects with other power relations, including race, class, and sexuality.

Courses allow students to develop a deeper understanding of how gender operates, and to transfer the analytical skills they acquire to other courses as well as to their personal and professional lives. The minor combines coursework in some combination of the following fields: English, history, anthropology, psychology, philosophy, economics, and modern languages.

Courses listed are only examples. Course offerings change regularly, so please consult semester offerings and the minor advisor for other courses.

The courses listed below are offered with at least general regularity. Participating departments may develop and offer other courses that, while not listed here, are appropriate for the study of gender. Consult the minor advisor to confirm the relevance of unlisted, gender-focused courses.

Complete 1 of the following required courses. 9 units

| | | |
|--------|--|---|
| 76-241 | Introduction to Gender Studies | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |

Complete 5 or more additional courses totaling at least 45 units. 45 units

See examples below, but other courses may fulfill this requirement.*

| | | |
|--------|---|-----|
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-422 | Gender and Sexuality Studies | 4.5 |
| 76-441 | Theorizing Sexuality | 9 |
| 79-244 | Women in American History | 9 |
| 79-320 | Women, Politics, and Protest ** | 9 |
| 79-323 | Making Modern Cities | 9 |
| 79-324 | #MeToo: Naming and Resisting Gender Violence | 6 |
| 79-325 | U.S. Gay and Lesbian History | 6 |
| 79-331 | Body Politics: Women and Health in America ** | 9 |
| 82-300 | Language & Society in the Arab World | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 85-350 | Psychology of Prejudice | 9 |
| 85-446 | Psychology of Gender | 9 |

* Consult with Gender Studies Minor Advisor Professor Lisa Tetrault at tetrault@andrew.cmu.edu.

** If not taken as a requirement.

Minor in Health Care Policy and Management

Sponsored by:

Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:

Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:

| | | |
|--------|--|---|
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 90-436 | Health Systems | 6 |
| 90-472 | Health Policy | 6 |

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses

| | | |
|--------|--|----|
| 94-409 | Healthcare Information Systems | 12 |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 90-834 | Health Care Geographical Information Systems | 12 |

Other courses as approved**Humanities and Social Sciences Courses (9 units each)**

| | | |
|--------|--|---|
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 42-444 | Medical Devices | 9 |

Other courses as approved

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

| | | |
|---|---------------------------|--------------|
| Health Management/Administration Focus | | Units |
| 90-832 | Health Law | 6 |
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |

| | | |
|----------------------------|--|--------------|
| Health Policy Focus | | Units |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 88-365/90-882 | Behavioral Economics and Public Policy | 9 |

Other courses as approved

| | | |
|--|--|--------------|
| Health Analytics & IT Focus | | Units |
| 94-409 | Healthcare Information Systems | 12 |
| 90-834 | Health Care Geographical Information Systems | 12 |
| 42-444 | Medical Devices | 9 |

Other courses as approved

The Minor in Linguistics

Linguistics is the scientific study of human language. The central goal of the Linguistics Program is to provide students with the analytical skills and linguistic concepts needed to understand language scientifically, whether formally, as researchers, or informally, as participants in daily linguistic interactions. The foundation of the Linguistics Minor is a set of rigorous core courses, informed by contemporary approaches to the study of linguistic form and meaning. The Core courses cover the principal domains of linguistic analysis: phonetics and phonology, syntax, and meaning. Students then move on to the Extended Core, which includes more advanced courses as well as courses on a wider range of topics, such as intonation and language variation. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

Core (27 units)

| | | |
|---------------------------------------|---------------------------|---|
| Required | | |
| 80-180 | Nature of Language | 9 |
| Select 2 from the following 3 options | | |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-280 | Linguistic Analysis | 9 |
| or 80-285 | Natural Language Syntax | |
| 80-381 | Meaning in Language | 9 |
| or 80-383 | Language in Use | |

Extended Core: Choose 3 courses (27 units) from the Extended Core and/or additional courses from Core.

| | | |
|----------------------|---|---|
| Extended Core | | |
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-284 | Invented Languages | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |

The Minor in Logic and Computation

The Minor in Logic and Computation provides students with general course work in logic, the theory of computation, and philosophy. Students must complete six courses, among them the following three core courses. All courses counted towards the minor must be taken for a letter grade and passed with a grade of "C" or above.

| | | |
|---|-----------------------------------|-----------------|
| Logic and Computation Core Courses | | 27 units |
| 80-150 | Nature of Reason | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| or 80-210 | Logic and Proofs | |
| 80-310 | Formal Logic | 9 |
| or 80-311 | Undecidability and Incompleteness | |

Logic and Computation Electives 27 units

Students must take two courses in the Philosophy Department at the 300-level or higher, in subjects related to logic and computation. And an additional course at the 300-level or higher in an area that uses logical and computational tools, such as philosophy, computer science, linguistics, mathematics, psychology, or statistics. The choice of electives must be approved by the Academic Program Manager.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*
<https://www.cmu.edu/ni/academics/minor-in-neural-computation.html>

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of

neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Neuroscience Institute (<https://www.cmu.edu/ni/>) and the Center for the Neural Basis of Cognition (CNBC) (<http://www.cnbc.cmu.edu/>).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

Students must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@andrew.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) - Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student's major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student's major or other minors. However, courses taken for general education requirements of the student's degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

| | | Units |
|--------|--|-------|
| 15-386 | Neural Computation | 9 |
| 15-387 | Computational Perception | 9 |
| 15-883 | Computational Models of Neural Systems | 12 |

| | | |
|-----------------------|---|---|
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 86-375 | Computational Perception | 9 |
| Pitt-Mathematics-1800 | Introduction to Mathematical Neuroscience | 9 |

B. Neuroscience

| | | |
|------------------------|--|----|
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 42-630 | Introduction to Neural Engineering (crosslisted with 18-690) | 12 |
| 85-765 | Cognitive Neuroscience | 9 |
| Pitt-Neuroscience 1000 | Introduction to Neuroscience | 9 |

C. Cognitive Psychology

| | | |
|--------|--|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-426 | Learning in Humans and Machines | 9 |
| 85-765 | Cognitive Neuroscience | 9 |

D. Intelligent System Analysis

| | | |
|-----------|---|----|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 15-387 | Computational Perception | 9 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-299 | Introduction to Feedback Control Systems | 12 |
| 16-311 | Introduction to Robotics | 12 |
| 16-385 | Computer Vision | 12 |
| 18-290 | Signals and Systems | 12 |
| 24-352 | Dynamic Systems and Controls | 12 |
| 36-225 | Introduction to Probability Theory | 9 |
| 36-247 | Statistics for Lab Sciences | 9 |
| 36-401 | Modern Regression | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 42-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |
| 86-375 | Computational Perception | 9 |
| 86-631 | Neural Data Analysis | 12 |

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is <https://www.cmu.edu/ni/academics/pnc/pnc-training-faculty.html>. The director

of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships (\$11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ (<http://www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/>) for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ (<http://www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/>) for application information.

The Minor in Rationality, Uncertainty, and Choice: Formal Methods

Core Requirements

| Complete all of the following: | Units |
|-------------------------------------|-------|
| 80-305 Game Theory | 9 |
| 80-306 Decision Theory | 9 |
| 88-223 Decision Analysis | 12 |
| or 88-312 Decision Models and Games | |

Note: Students must complete three elective courses from the following two categories and must complete at least one course in each category.

| Elective Category 1: Formal Foundations | 9-18 units |
|---|------------|
| 80-201 Knowledge and Justified Belief | 9 |
| 80-208 Critical Thinking | 9 |
| 80-210 Logic and Proofs | 9 |
| 80-315 Modal Logic | 9 |
| 80-325 Foundations of Causation and Machine Learning | 9 |
| 80-516 Causality and Machine Learning | 9 |
| 80-521 Seminar on Formal Epistemology: Belief and Evidence | 9 |
| 80-524 Topics in Formal Epistemology: Topological Philosophy of Science | 9 |
| 88-223 Decision Analysis | 12 |
| 88-312 Decision Models and Games | 9 |
| 88-379 Data-Driven Decision Analysis | 9 |
| Elective Category 2: Theory and Applications | 9-18 units |
| 80-246 Moral Psychology | 9 |
| 80-249 AI, Society, and Humanity | 9 |
| 80-252 Kant | 9 |
| 80-255 Pragmatism: Making Ideas Work | 9 |
| 80-261 Experience, Reason, and Truth | 9 |
| 80-321 Causation, Law, and Social Policy | 9 |
| 80-324 Philosophy of Economics | 9 |
| 80-330 Ethical Theory | 9 |
| 80-335 Social and Political Philosophy | 9 |

The Minor in Religious Studies

Professor Allyson Creasman, *Faculty Advisor*, History Department
Location: Baker Hall 242D, 412-268-9832
acreasman@cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

The Religious Studies minor offers students a range of intellectual tools for thinking about religious ideas, behaviors and institutions. It also enables students to build a base of knowledge that extends beyond any one particular religious tradition.

Curriculum

54 units

The minor consists of six courses, totaling at least 54 units. Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Religious Studies minors must satisfy the requirements listed below:

Required Core Course

9 units

All Religious Studies minors are required to take 79-281, Introduction to Religion. This required course introduces several modes of inquiry into religion, such as the philosophy of religion, sociological and behavioral approaches to religion, historical analysis of religious subject, literary and critical analysis of religious texts, theological modes of thought, and anthropological treatments of religion. This course is offered regularly, usually in the Spring semester.

| | | |
|--------|--------------------------|---|
| 79-281 | Introduction to Religion | 9 |
|--------|--------------------------|---|

Distribution Requirements

18 units

In addition to the required Core Course, students must complete Distribution Courses totaling 18 units (usually two 9-unit courses). A Distribution Course is one that applies a particular discipline to more than one religion. Some examples of qualifying Distribution Courses that have been offered include:

Historical Approaches

| | | |
|--------|---|---|
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-352 | Christianity Divided: The Protestant and Catholic Reformations, 1450-1650 | 9 |

Philosophical Approaches

| | | |
|--------|------------------------|---|
| 80-276 | Philosophy of Religion | 9 |
|--------|------------------------|---|

Textual Approaches

| | | |
|--------|--|---|
| 76-331 | Dissenters and Believers: Romantics, Revolution, and Religions | 9 |
|--------|--|---|

In addition to the courses listed above, participating departments often offer other courses that may qualify as Distribution Courses for the minor. The Faculty Advisor should be consulted to identify qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

Elective Courses

27 units

In addition to the required Core Course and the Distribution Courses, students must complete Elective Courses totaling at least 27 units (usually three 9-unit courses). Unlike Distribution Courses, an Elective Course may focus on the study of only one religion (although courses examining more than one religious tradition can also count as Elective Courses if not otherwise used to fulfill the Distribution Requirement).

Some examples of qualifying Elective Courses that have been offered include:

| | | |
|--------|--|---|
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-296 | Religion in American Politics | 6 |
| 79-350 | Early Christianity | 9 |
| 79-375 | Science & Religion | 6 |

In addition to the courses listed above, participating departments often offer other courses that may qualify as Elective Courses for the minor. The Faculty Advisor should be consulted to identify qualifying courses (especially after the Schedule of Courses for a given semester becomes available).

In addition to courses offered at CMU, relevant courses taken at the University of Pittsburgh, Duquesne University, or other Pittsburgh

institutions may count toward the Elective Requirement with the permission of the Religious Studies minor's Faculty Advisor. The option to cross-register for relevant courses at other local institutions allows students some flexibility in meeting the minor's requirements and gives them the opportunity to explore interests in religious subjects that might not otherwise be covered at CMU. Students who wish to cross-register for courses at other institutions should consult with the Faculty Advisor about whether the selected course(s) will meet the minor's Elective Requirement.

The Minor in Science, Technology and Society

Professor Christopher J. Phillips, *Faculty Advisor*, History Department
Location: Baker Hall 231C, 412-268-1753
cjp1@cmu.edu

Dr. Alexandra Garnhart-Bushakra, *Academic Program Manager*, History Department
Location: Baker Hall 240, 412-268-2880

This minor provides interdisciplinary perspectives on the development and meaning of science and technology in modern society. The core courses enable you to develop a historical and philosophical understanding of the interplay among science, technology, and society. Elective courses enable you to pursue in greater depth and variety subjects and approaches that build on both the core courses and your primary major.

Courses taken to fulfill requirements in other major or minor programs may only be applied to this minor with permission of the Faculty Advisor.

Curriculum **54 units**

Core Courses **27 units**

Complete one course from each area. Additional courses from the History of Science Core and the History of Philosophy Core may count as electives for the minor.

Area 1. History of Science Core

Take at least 1 course from the list below.

| | | |
|--------|---|---|
| 79-160 | Introduction to the History of Science | 9 |
| 79-170 | Introduction to Science, Technology, and Society | 9 |
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-234 | Technology and Society | 9 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

Area 2. Philosophy of Science Core

Take at least 1 course from the list below.

| | | |
|--------|--------------------------------------|---|
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |

Area 3. Science Core

Take at least 1 course (9 units total) from the following departments: 15-xxx Computer Science, 09-xxx Chemistry, 03-xxx Biological Sciences, 33-xxx Physics

Electives **27 units**

Complete three courses from the approved list of elective courses. Courses listed in Areas 1 and 2 may also be taken as electives if not already completed for an Area requirement. To petition for a course not listed to be approved as an elective, contact the Faculty Advisor, cjp1@cmu.edu, directly.

| | | |
|--------|---|----|
| 18-482 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 48-448 | History of Sustainable Architecture | 9 |
| 73-427 | Sustainability, Energy, and Environmental Economics | 9 |

| | | |
|--------|---|---|
| 76-319 | Environmental Rhetoric | 9 |
| 76-395 | Science Writing | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-492 | Rhetoric of Public Policy | 9 |
| 76-494 | Healthcare Communications | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-204 | American Environmental History | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-246 | Industrial America | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-297 | Technology and Work | 9 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 79-303 | Pittsburgh and the Transformation of Modern Urban America | 6 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-357 | Science and the Body | 6 |
| 79-368 | Un-natural Disasters: Societies and Environmental Hazards in Global Perspective | 6 |
| 79-372 | The Rise and Fall of Pittsburgh Steel | 6 |
| 80-101 | Dangerous Ideas in Science and Society | 9 |
| 80-150 | Nature of Reason | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 85-380 | In Search of Mind: The History of Psychology | 9 |

The Minor in Societal & Human Impacts of Future Technologies (SHIFT)

| | | |
|--|---------------------------|-------|
| Core Courses (2 courses, 10 to 18 units total) | | Units |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-445 | Shift Capstone Experience | 1-9 |

Area Courses (6 courses, 54 units total)

Note: Five of the six Area Courses must be taken in different departments

Technology area (18 units)

Courses that build basic technological competence, and teach concepts and frameworks that provide high-level understanding of computational technologies, including their possibilities and limits.

| | | |
|----------------------|---|-------|
| Complete two courses | | Units |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-320 | Social Web | 12 |
| 05-452 | Service Design | 12 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 16-467 | Human Robot Interaction | 12 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | 9 |
| 17-313 | Foundations of Software Engineering | 12 |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-355 | Program Analysis | 12 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 67-250 | The Information Systems Milieux | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Social & Behavioral Sciences area (18 units)

Courses that teach the concepts and frameworks of social and behavioral sciences (e.g., economics, psychology, sociology), including methods and

analyses such as experimental design and quantitative and qualitative data analysis.

| Complete two courses | Units |
|--|-------|
| 05-413 Human Factors | 9 |
| 17-224 Influence, Persuasion, and Manipulation Online | 9 |
| 36-200 Reasoning with Data | 9 |
| 70-311 Organizational Behavior | 9 |
| 70-321 Negotiation and Conflict Resolution | 9 |
| 70-341 Team Dynamics and Leadership | 9 |
| 73-102 Principles of Microeconomics | 9 |
| 73-103 Principles of Macroeconomics | 9 |
| 84-266 Research Design for Political Science | 9 |
| 84-267 Data Science for Political Science | 9 |
| 84-369 Decision Science for International Relations | 9 |
| 88-406 Behavioral Economics @ Work | 9 |
| 88-418 Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 International Negotiation | 9 |
| 88-435 Decision Science and Policy | 9 |

Ethics, Policy & Design Area (18 units)

Courses that teach core concepts and frameworks to address and analyze ethical, policy, and design challenges relevant to current and near-future computational technologies.

| Complete two courses | Units |
|--|-------|
| 05-413 Human Factors | 9 |
| 08-200 Ethics and Policy Issues in Computing | 9 |
| 16-161 ROB Freshman Seminar: Artificial Intelligence and Humanity | 9 |
| 17-224 Influence, Persuasion, and Manipulation Online | 9 |
| 36-200 Reasoning with Data | 9 |
| 51-173 Design Center: Human Experience in Design | 9 |
| 51-241 How People Work | 9 |
| 51-371 Futures I | 4.5 |
| 51-373 Futures II | 4.5 |
| 51-382 Design Center: Design for Social Innovation | 9 |
| 70-311 Organizational Behavior | 9 |
| 70-321 Negotiation and Conflict Resolution | 9 |
| 70-332 Business, Society and Ethics | 9 |
| 70-341 Team Dynamics and Leadership | 9 |
| 70-364 Business Law | 6 |
| 73-102 Principles of Microeconomics | 9 |
| 73-103 Principles of Macroeconomics | 9 |
| 79-175 Moneyball Nation: Data in American Life | 9 |
| 79-234 Technology and Society | 9 |
| 79-302 Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-130 Introduction to Ethics | 9 |
| 80-135 Introduction to Political Philosophy | 9 |
| 80-330 Ethical Theory | 9 |
| 80-335 Social and Political Philosophy | 9 |
| 84-266 Research Design for Political Science | 9 |
| 84-267 Data Science for Political Science | 9 |
| 84-275 Comparative Politics | 9 |
| 84-319 Civil-Military Relations | 9 |
| 84-325 Contemporary American Foreign Policy | 9 |
| 84-369 Decision Science for International Relations | 9 |
| 84-370 Nuclear Security & Arms Control | 9 |
| 84-372 Space and National Security | 9 |
| 84-373 Emerging Technologies and International Law | 9 |
| 84-380 US Grand Strategy | 9 |
| 84-386 The Privatization of Force | 9 |
| 84-387 Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-389 Terrorism and Insurgency | 9 |
| 84-390 Social Media, Technology, and Conflict | 9 |
| 84-405 The Future of Warfare | 9 |
| 88-221 Markets, Democracy, and Public Policy | 9 |
| 88-406 Behavioral Economics @ Work | 9 |
| 88-418 Negotiation: Strategies and Behavioral Insights | 9 |

| | |
|------------------------------------|---|
| 88-419 International Negotiation | 9 |
| 88-435 Decision Science and Policy | 9 |

The Minor in Sociology

Peter Schwardmann, *Faculty Director*

Connie Angermeier, *Senior Academic Program Manager and Advisor*

Location: Porter Hall 208H

cla2@andrew.cmu.edu

Schedule an appointment: <https://go.oncehub.com/ConnieAngermeier> (<https://go.oncehub.com/ConnieAngermeier/>)

The Sociology minor introduces the student to central concepts in sociological theory and methods of empirical inquiry needed to broadly understand social behavior, including its structure, history, and dynamics. Students choose among a range of methodological approaches and substantive topic areas including social psychology, work and organizations, social networks, technology and society, medical sociology, and gender and family. Exposure to these topics will help students understand and appreciate the processes by which families, groups, and organizations form and evolve over time; by which individuals affect and are affected by the society in which they live; and by which technology and institutions shape and influence society. This background in empirical tools and social theory will strengthen the student's ability to pursue graduate studies in sociology, social history, social science, and organizational theory; to begin professional careers involving social analysis, network analysis, data analysis of teams, groups and organizations, social analysis within journalism, political institutions, the government, and online; and to enter the corporate environment with a thorough understanding of organizational activity.

Curriculum

54 units

In addition to the general education requirements of the student's college and the requirements of the student's major, Sociology minors must satisfy the following requirements. The Core courses comprise 18 units of the minor. One course is taken from the Organizations cluster, and one course is taken from the Methodology cluster. The Elective courses comprise 36 units of the minor. Sociology minors should consult with the program advisor to plan a course schedule prior to registration.

NOTE: The core courses are offered regularly; the elective courses are offered with at least general regularity. Participating departments may subsequently develop and offer other courses that, while not listed here, are deemed appropriate for this minor. The program advisor should be consulted (especially when the schedule of courses to be offered for a given semester becomes available) to identify such additional courses.

No more than two courses (18 units) in the Sociology minor may be counted to fulfill any other major or minor's requirements.

Core Courses 18 units

A. Organizations

Complete one course.

| | |
|--------------------------------|---|
| 70-311 Organizational Behavior | 9 |
|--------------------------------|---|

B. Methodology

Complete one course.

| | |
|---|---|
| 36-202 Methods for Statistics & Data Science | 9 |
| 70-208 Regression Analysis | 9 |
| 85-310 Research Methods in Cognitive Psychology | 9 |
| 85-340 Research Methods in Social Psychology | 9 |
| 88-251 Empirical Research Methods | 9 |
| 88-252 Cause and Effect | 9 |

Elective Courses 36 units

Complete four courses (a minimum of 36 units) from the following list. Two courses (18 units) must be taken from one category to complete the depth requirement. One course (9 units) must be taken from the other category. The remaining course (9 units) may be taken from either category. Appropriate courses offered by the Department of Sociology at the University of Pittsburgh (available during the academic year through cross-registration) may also be included as part of this option. Contact the Sociology program advisor for more information.

1. Sociology of Gender, Family, and Culture

| | |
|---------------------------------------|---|
| 70-342 Managing Across Cultures | 9 |
| 70-385 Consumer Behavior | 9 |
| 76-241 Introduction to Gender Studies | 9 |

| | | |
|---|---|----|
| 79-244 | Women in American History | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-308 | Crime and Justice in American Film | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-323 | Making Modern Cities | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-256 | Modern Moral Philosophy | 9 |
| 80-305 | Game Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 85-241 | Social Psychology | 9 |
| 85-350 | Psychology of Prejudice | 9 |
| 85-352 | Evolutionary Psychology | 9 |
| 85-358 | Pro-Social Behavior | 9 |
| 85-377 | Attitudes and Persuasion | 9 |
| 85-442 | Health Psychology | 9 |
| 85-446 | Psychology of Gender | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |
| 2. Sociology of Work, Organizations, and Technology | | |
| 70-332 | Business, Society and Ethics | 9 |
| 73-348 | Behavioral Economics | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 88-255 | Strategic Decision Making | 9 |
| 88-261 | Health Policy | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-341 | Team Dynamics and Leadership | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-451 | Policy Analysis Senior Project | 12 |
| 88-452 | Policy Analysis Senior Project | 12 |

Note: Some courses have additional prerequisites.

Dietrich College Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

Dietrich College Interdisciplinary Courses

66-101 Dietrich Introductory Seminar: College & University Success Strategies

Fall: 3 units

This interactive course is designed to help new students transition successfully to academic and student life in the Dietrich College at Carnegie Mellon. Students will explore campus resources and opportunities; their skills, identity, interests, and goals; and strategies for personal and academic success to help them make the most of their Dietrich experience. This course is intended to be taken by first year students in their first semester at Carnegie Mellon.

66-106 Applied Quantitative Social Science I (QSSS students)

Fall: 9 units

The first course in the QSSS core sequence provides a fast-paced introduction to a range of methods in the quantitative social sciences. Organized around a set of case studies, the course introduces the language and methods of empirical research through a combination of seminar-style discussions of academic papers, and hands-on lab work using the statistical software R. Students will replicate results from a high-profile labor market discrimination paper, explore agent-based models of neighborhood segregation, and scrape Wikipedia data to examine imbalances in gender representation. Enrollment restricted to QSSS students.

66-122 DC Grand Challenge First-Year Seminar: Beyond Earth

Spring: 9 units

The aim in the course is to foster in students a planetary perspective, to see Earth in its context of the cosmos and to see humans in their relation to real or possible forms of life in the universe. The obsession with outer space is found among scientists, business people and politicians, in deed and story, in film and even computer games. If we are to fully appreciate the potentials of space, we must also consider the search for intelligent life in its scientific and societal aspects, and investigate how we could adapt our systems of communication to reach species across distances that may be physically insurmountable. This interdisciplinary course will be taught by scholars from distinct cultural and linguistic backgrounds. Course materials will be taken from scientific literature, the history of science, and science fiction. We will explore scientific writing and reasoning, the space race between global powers, space travel and colonization, and the promise and pitfalls of interspecies and interspace communication. A planetary perspective, once achieved, can change the way one sees other inhabitants of this planet - as partners in survival in a universe which sets enormous odds against it, or as unwelcome intruders grasping for scant resources within this thin epidermis of soil, air, and water which surrounds Earth and makes our lives possible.

66-123 DC Grand Challenge First-Year Seminar: Science on Stage

Spring: 9 units

Art and Science and #8212; two fields of study that are most often considered diametrically opposed. Art is frivolous entertainment. Science is hard rational fact. In this Grand Challenge course, we hope to break that supposition or at least examine it in great detail. Specifically, we will use theater to argue that drama can produce challenging, demanding and intelligent work that showcases the impact of science on current discourse. We want to link the two cultures. The word "theater" has the same etymological root as "theory" - both words come from the Greek thea meaning view. This shared origin demonstrates ways we can work to analyze and interpret both fields and show the common ground between these two cultures. As we attend to plays and writing ranging from Tom Stoppards Arcadia and Michael Frayns Copenhagen to Caryl Churchills A Number and Oliver Sacks Man Who Mistook his Wife for a Hat, our class discussions will consider questions that include: Why is science a trend in contemporary theater? Does it reflect on our dependence on technology? What kinds of questions are being asked when science or scientific theory is presented on the stage? Are people attracted to plays about science because of their difficult subject matter or does it lack the engagement of popular culture? In addition to integrating humanities and scientific approaches within Dietrich College, this course will utilize the expertise of both individuals in the School of Drama and the producers in the local theater community, and local science writers. Finally, in addition to weekly writing assignments, the course will ask students to produce original dramatic scenes that incorporate scientific exploration which will, ultimately, lead to staged readings of their work.

66-125 DC Grand Challenge First-Year Seminar: Democracy & Data

Fall: 9 units

From gerrymandering to online political ads, data is being used in ways that raise urgent questions about the integrity of democratic elections. But the relationship between democracy and data goes far beyond elections. In a world of constant surveillance, in which vast amounts of data are gathered from our phones, our computers, and from other facets of our lives - and in which new breakthroughs in machine learning and data analytics make such data dramatically more powerful - what does it mean for average citizens to have control over their own lives? What does democracy mean?

66-126 DC Grand Challenge First-Year Seminar: Voting: An American Tradition

Fall: 9 units

This course investigates the sacred American practice of voting, the cornerstone of American democracy, using the 2020 election cycle as our laboratory. The course uses a multi-disciplinary approach, examining the topic from several different perspectives. We'll investigate social movements to expand the vote, the role of technology, game theory, polling, predictions, electoral mapping, social media, the structures of American governance, and more. Questions include: What is the electoral college? Who gets to vote and why? How well is that vote accounted for? How can voting systems be compromised? Why is it so hard to predict who will win? How do people make decisions? How useful are polling and amp; predictions? What disrupts voting? Why is turnout so low? How does money play a role in the election cycle? Why do we vote the way we do? How is social media changing elections? What are global best practices? Did the founders even intend for a mass democracy? (The answer is no!) Many of you will be first-time, eligible voters in one of the most remarkable presidential campaigns in American history. We'll build your skills as new democratic citizens, of this nation or others, and help you make sense of the history-making U.S. news cycle. A note on partisanship: All political viewpoints are welcome in this class. This is a course on how we navigate and account for political difference in a diverse, disparate nation. This is something we'll practice in class, while we will also study that very process across the nation.

66-127 DC Grand Challenge First-Year Seminar: Environmental Justice

Fall: 9 units

Wondering what the "Green New Deal" proposal is about? Does it seem like you have to choose between protecting people and protecting the planet? How does environmentalism connect to struggles over social justice and human rights? This first-year interdisciplinary seminar is an introduction to the Grand Challenge: Environmental Justice. In Giovanna de Chiro's words, the environmental justice movement is working "toward building diverse, dynamic, and powerful coalitions to address the world's most pressing social and environmental crises global poverty and global climate change by organizing across scales and 'seeking a global vision' for healthy, resilient, and sustainable communities." In this seminar, we'll study the history and science behind two interconnected challenges for environmental justice: global climate change and fine-particulate air pollution. Both types of pollution start with combustion of fossil fuels. Particulate air pollution kills roughly 7 million globally each year; these air pollution deaths happen close to the source, with unequal levels of exposure and risk for people according to class and race. Climate change, mostly from carbon dioxide and methane emissions, is spread globally and lasts well beyond our lifetimes, yet the effects are again disproportionately based on class and race. In this course, we'll explore the science, history, ethics, and public perception of these problems, with implications for Pittsburgh and the planet, and for the near- and long-term future.

66-128 DC Grand Challenge First-Year Seminar: Palestinian and Israeli Food Cultures

Spring: 9 units

In a region beset by conflict, how do food cultures allow us to approach cultural intersections and connections? This course is designed to provide students with a historical, cultural, and linguistic understanding of the hybrid nature of Jewish and Arab cultures, and the multiple ethnic contributions to local food cultures in Israel and Palestine. The two instructors, from the fields of Jewish history and Arabic Studies, will introduce students to the history, literature, film, and languages of the region, as well as to critical scholarship on food and foodways in the Palestinian and Israeli context. Students will have the opportunity to engage in cooking either locally or in Philadelphia - subject to travel restrictions - and to learn from Michael Solomonov and Reem Kassis, two award-winning US-based celebrity chefs and authors of Israeli and Palestinian cook books respectively. Throughout the semester we will also host a range of guest speakers who will deliver lectures on our course topic in the classroom and in the community.

66-129 DC Grand Challenge First-Year Seminar: Unreality: Immersive and Spatial Media

Intermittent: 9 units

Virtual news stories and game worlds are accessible by putting on cardboard goggles, theme parks are engineered to provide convincing multisensory experiences, and workforces are reliant on augmented views of factory floors. Immersive and spatial media constitute a suite of emerging technologies that offer the opportunity to expand arts, entertainment, science, design, commercial enterprises and countless other domains in ways that were previously limited to science fiction. The potential for augmented reality to disrupt our current technological ecosystem is tremendous. Many of these technologies are now 50 years old and just starting to enter the commercial realm. As immersive experiences and augmented realities become more integrated into our work and leisure, do we need to worry about the ways that unreality affect our experiences of reality, or our interactions with each other? How do we know that we can trust our senses to tell us what is real? How do we begin to grapple with the ethical, cultural, social, technological, and regulatory implications of this shift?

66-131 DC Grand Challenge First-Year Seminar: Culture, Sports, and Conflict in/and VR

Intermittent: 9 units

Sports have been celebrated for bringing people together; yet, sports have also been a locus of tensions and conflict that most of us only experience from the sidelines. We understand sports, the people, and their cultural impact through the stories that we tell about them in such places as museums, stadium tours, and Halls of Fame as well as in books, documentaries, and podcasts. Through immersive technologies, these stories are brought to life and bring fans to the heart of the action. In this course, students and faculty together will seek to achieve two main objectives: (1) examine ways in which cultural and societal values are reflected in sports and (2) how Virtual Reality (VR) technology can help design experiences that enhance the users awareness of these issues by engaging with these cultural and societal perspectives. We will first unpack sports stories that are squarely situated at the crossroads of sports and culture(s) (e.g., racism, human rights, and the role of government and/in national politics). Then we will explore the role of VR technology to help craft these narratives. Students, then, will discover what it means to write stories for VR experiences. The course will culminate in students designing an immersive experience about a sports conflict of their choice, which will be developed more fully to be displayed in the Askwith Kenner Global Languages and Cultures Room.

66-132 DC Grand Challenge First-Year Seminar: Health in Unhealthy Times

Intermittent: 9 units

We live in times when health is a major global concern, whether we worry about the increase in Covid-19 cases, await our immunization, strive to understand the disproportionate impact of the disease on BIPOC populations, or debate mitigation measures not to mention ongoing concerns with common chronic illnesses such as diabetes, cancer, autoimmune disease, depression, anxiety, etc.. Health, or lack thereof, has always been a critical part of the human experience, and it is fundamentally impacted by different human experiences. This seminar will introduce students to the scientific aspects of health, its political and social determinants, ethical constraints, historical roots, as well as to the cultural and communicative skills required to dialogue about health, make decisions, and engage empathically with others in their health stories. We will read and discuss a broad variety of materials from medical science articles to social psychological experimental reports and personal or literary narratives about health. The course is divided into three components: health and preventative behaviors, managing chronic health challenges, and coping with disruptive health experiences. We believe these components can represent a broad array of interest and engage students on a personal level.

66-133 DC Grand Challenge Seminar: We're Not Beyond Race: Race and Identity in America

Intermittent: 9 units

Race matters. How have social institutions and historical factors led to the belief systems and stereotypes that shape how race is experienced in American society, and how do these belief systems affect the way individuals come to view and define themselves and others? This course considers how race and identity affect peoples lived experiences - how they think, feel, and act - in America. In this course, we will examine the structural and systemic origins of the racial status quo, as well as the way that individuals navigate the social and racial landscape of modern-day America. Including insights from psychology, literature, economics, sociology, and history, the course will focus on how race matters at both a societal level and an individual level. We will consider different racial situations throughout American society to understand how individuals navigate and experience race and identity. Throughout the course, we will watch films, read literature, and analyze music and art that reflect the experience of race and identity.

66-134 DC Grand Challenge First-Year Seminar: Native Americas: Facts and Fictions

Intermittent: 9 units

How did Indigenous people respond to the challenges of populating the American hemisphere and creating complex, diverse and dynamic cultures, languages and political entities? How did they survive, adapt to, and resist the conquest and colonization of their lands, and ensuing social and cultural dislocations? How have they resurged politically, culturally, artistically and intellectually in recent years? This course considers the history, experiences, and perspectives of native populations across the Americas. It seeks to reckon with the facts of the Native American experience, while challenging the fictions of stereotypes and narratives that have often relegated Indigenous people to the social and cultural margins of the nations in which they now live. After introducing students to a few of the myriad Indigenous groups of North, Central and South America, we will then survey the implications of the era of European conquest and colonization. We'll consider the implications of the rise of new nations in the Americas, as new and intensifying campaigns of violence were unleashed against Indigenous populations. We will consider the rise of Native American civil rights and political and cultural sovereignty movements from the late 20th century forward, as they coalesced into major political challenges to native marginalization and demands for recognition and reparation of historical injustices. Finally, we will explore how contemporary Indigenous artists, authors, and political and social activists are reimagining indigeneity (the condition and experience of being Indigenous) in ways that demonstrate how indigeneity is not a fixed kind of identity, not one that is confined or defined in any way by a static conception of tradition, but rather one that challenges the present and reimagines the future in dynamic and creative ways.

66-135 DC Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Intermittent: 9 units

This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

66-136 DC Grand Challenge First-Year Seminar: Becoming Resilient in Challenging Times

Spring: 9 units

"My heart is in my work" - a phrase that once rang true to many CMU students and remains the motto our institution lives by. But what happens if life has been interrupted by a global pandemic and our hearts suddenly aren't in our work anymore? How do we as a society respond to challenges and struggles that go beyond our daily work routine and encompass threats to our physical and mental health, social interactions, family life, and hobbies and leisure activities? Today, when the "new normal" seems to be lasting forever and we face an unprecedented mental health crisis, how can we address questions of resilience, wellbeing and perseverance in the classroom, both from an academic and a personal point of view? How can we rebuild communities and societies after traumatic and scarring events, communicate and collaborate across disciplines to solve complex problems, and establish a world where we thrive and succeed again? In a more fundamental way, what does it mean to be resilient, and where is the boundary between our own health and wellness and the cultural, societal, or economic expectations around these ideas? To answer these questions, this course will use graphic novels from English-speaking, German-speaking, and Spanish-speaking countries as its core to introduce students to a variety of graphic approaches to the concept of resilience, including from the graphic medicine genre. We will explore mental and physical health and healing in innovative ways to analyze different perspectives on and models for wellbeing. Working comparatively across cultures, the graphic novels in the course will help re-examine and re-define our understanding of wellbeing and health and explore how visual storytelling can drive social change around issues of individual and community resilience.

66-137 DC Grand Challenge Seminar: Causes and Consequences of Health Disparities

Spring: 9 units

Why do some people live well into their nineties while others are more likely to die at an earlier age? The answer to this question can be more complex than one might think. Life expectancy can be influenced by a host of individual and population-level factors. This course is designed to critically examine the social factors research has found to impact individual and population health experiences. This course will introduce students to the multiple approaches to researching the complex problem of health disparities in the United States with particular emphasis on perspectives from the social sciences and humanities. Specifically, students will examine how factors such as socioeconomic status, education, crime, housing, health care and food availability play important roles in the production of disparate health. Students will examine psychological factors that can create disparate health experiences and the impact of such disparities on psychological health. We will address health disparities at the individual and population levels, learning how disparate health experiences are historically and socially produced, and how such disparities produce negative physical and mental health outcomes for individuals and minoritized populations. At the end of the course, students will present a collaborative group project that examines a specific facet of US health disparities and offer a proposed solution. Using a multi-disciplinary perspective, we will challenge students to discover just how important seemingly unimportant interpersonal and structural factors can be in explaining health disparities and how important it is for society to take measures to address these disparities.

66-138 DC Grand Challenge First-Year Seminar: Militarizing Freedom Arms in U.S. Culture

Spring: 9 units

This seminar examines the way American culture and politics have utilized the tools, tactics, and values of the military during both war and peacetime. Utilizing several disciplinary perspectives, including history, rhetorical criticism, fictional narrative, and the discourse of public policy, we will consider the different ways that gun culture, military mobilization, veteran affairs, and police power have influenced American society, including how people relate to or fear one another. We will explore some historical roots of the U.S.'s militarized culture, alongside the linguistic, argumentative, and narrative trends that have contributed to urgent democratic issues like police brutality, domestic terrorism, and the rise of the carceral state. This course will address themes and questions such as: - American exceptionalism: Does violence play an extraordinary role in American and culture, in contrast to other nations? What are its historical antecedents? - The escalation of violence in American political culture: Why does political polarization engender violence? Do traditional appeals to "freedom" accelerate such violence? - How has America become a country of prisons and mass incarceration? - Global impacts: How does the U.S.'s militarized political culture impact nations and people beyond its borders?

66-139 DC Grand Challenge Seminar: Reducing Conflict Around Identity and Positionality

Spring: 9 units

Learning to reduce conflict requires understanding positionality and identities, and why and how societies build barriers in their populations. In this interdisciplinary course, students will learn how to talk to each other and strangers about identity: its defining characteristics and how our bias influences our judgments. The social sciences elements will stress Social Identity Theory, bias, stereotypes, and in-groups and out-groups. The humanities elements will include close-reading strategies and incorporate conceptual frameworks from cultural studies, literary studies, and narrative theory. In addition to practicing the methodologies in these two disciplines, students will undertake two projects. In the first project, they will develop and implement a semi-structured interview protocol for their campus peers centered around belonging. In the second project, students will employ close reading techniques to analyze Young Adult novels that address complex questions of identity, isolation, bias, and rejection. Working with one novel and Project 1 data, each team of social sciences, humanities, and data specialists will create a website to highlight inclusive successes and challenges. This final cohesive 'picture' of themes pertaining to feelings of belonging on our campus will help guide the CMU community toward deeper understanding and acceptance practices.

66-140 DC Grand Challenge 1st Year Seminar: Intersecting Identities in Higher Education

Spring: 9 units

Higher education classrooms bring together students from a wide variety of backgrounds and prior experiences. While students' intersecting identities can be an asset in the classroom, they can also present challenges in terms of student learning. For example, how might coming from a low-resource school system impact a student's achievement at the college level? How might the learning experiences of neurodiverse students or international students differ from those of neurotypical or US-born students? Through class discussions, guest speakers, and course assignments, students will have the opportunity to examine barriers to equitable education (e.g., gender, socioeconomic status, linguistic/cultural background, etc.) and initiatives designed to mitigate these barriers. Through reflective assignments, students will also have an opportunity to examine their own intersecting identities and identify what challenges or opportunities may have shaped their own learning. Over the course of the semester, students will work on a group project that asks them to explore different intersecting identities and how these identities may impact educational experiences. Finally, students will connect with campus stakeholders who advocate for educational equity at CMU, and create resources to help current and future CMU students thrive in CMU's diverse higher education classrooms.

66-141 DC Grand Challenge Seminar: Freedom of Speech & Academic Freedom

Intermittent: 9 units

This Grand Challenge course offers a comprehensive exploration of the principles, controversies, and significance of Freedom of Speech (FOS) and Academic Freedom (AF). By exploring actual and hypothetical cases, students will analyze the complex dilemmas that arise when we try to balance two interests: maximizing freedom of expression and creating an inclusive, respectful community. By engaging a wide range of disciplinary perspectives and methods of inquiry from philosophy, history, psychology, law, etc., students will examine how different policies and norms impact these competing interests and vice versa. Students will practice informed and constructive dialogue within the seminar to facilitate independent thought, rigorous inquiry, and how to discuss difficult topics productively. Course topics will include: - the rights and responsibilities involved in FOS for both individuals and institutions, - the history and current state of the law with respect to FOS, - the history and state of university policies and practices about AF for research and education, including scholarship, artistic freedom, teaching, in particular trigger warnings, safe spaces, censorship, protest, and controversial outside speakers, - developmental perspectives on how children learn about freedom of expression, - FOS in advertising, media, and social media, including recommendation algorithms. The broader goal is to empower students to become informed, responsible, and productive members of Carnegie Mellon's transformative university community.

66-142 DC 1st Year Seminar: The Mirror of Technology: Biases in Computation & Cognition

Spring: 9 units

The title of the show, Black Mirror, refers to the blank screens of tech devices that reflect back an image of the human user. The image captures some parts of us, say our facial expression, while deemphasizing, distorting or missing others, say the color of our eyes or skin. Further, the reflection is silent about what goes on under the surface in our heads, what we feel, think and value. At the same time, the screen presents a cover for a computational device which, when activated, is massively interconnected with local and global structures around us and with our minds in ways that we do not notice. Can we understand and explain this increasingly symbiotic relation, sometimes healthy, sometimes not? Through active discussion, group work, engaging with local and national experts, and argument and analysis in written work, we will explore the ways in which recent technologies mirror our minds as well as how our minds are impacted by and come to mirror those technologies. We will focus on the idea of bias and a type of informational selectivity we capture as attention. Topics will include: the nature of meaning, thinking and understanding in animals and machines, tests for cognition in artificial systems with focus on recent large language models such as CHAT GPT, biases in cognition and attention in humans and biases in algorithms and the impacts of these on society, the attention economy and the manipulation of our attention therein, and the symbiosis between mind and machine where machines extend our minds. These topics span philosophy, cognitive science and computer science. Our goal will be to acquire the analytical skills needed to help critically engage with and transform this symbiotic relation between mind and machine, moving it systematically towards a virtuous and healthy state.

66-143 DC Grand Challenge Seminar: Realizing Human Rights

Spring: 9 units

This course will introduce first year students to the challenge of protecting and promoting human rights in a world fraught with conflict, political strife, economic exploitation, and environmental hazards. We will focus on how human rights frameworks can be used to make the world more just, equitable, and free. We will begin by discussing the theoretical foundations of human rights and the development of human rights institutions in the 20th century. Students will learn how rights have been constructed through legal action, activism, and treaty negotiations in the past and examine the emergence and contestation of new rights today. We will explore why particular rights frameworks are privileged in some societies but not others. We will then focus on how practitioners investigate and document potential rights violations around the world, including in our own backyard. The instructors bring disciplinary expertise in history, journalism, and data analysis, and the course will feature guest lectures by legal experts and human rights practitioners. Topics covered will include genocide and other war crimes; political repression; economic, social, and cultural rights; environmental rights; migration and refugees; gender identity and sexuality; and indigenous rights. By the end of semester, students will be prepared to propose an action plan to address a specific human rights challenge in a community that they are familiar with. In previous semesters, our students have worked on projects related to deaths in Pennsylvania's jails and prisons in partnership with local organizations, proposed a project to assess human rights violations of migrants at the US/Mexico border, and conducted an international open source investigation of human rights violations using online media and satellite imagery.

66-144 DC Grand Challenge Seminar: In Transit: Exile, Migration, and Culture

Spring: 9 units

The world is currently experiencing the worst refugee crisis since the end of World War II. Large numbers of people are forced from home for political, personal, or racial reasons, and many others leave home because of grinding poverty and need. Conflicts about the mass migration provoked by this crisis have emerged all over the globe, from the United States, Latin America, and Europe, to Africa, the Middle East, Asia, and even Oceania. Writers, filmmakers, and artists have attempted to address the plight of refugees and migrants in their works, and many writers, filmmakers, and other artists are themselves refugees or migrants. Pittsburgh has a unique institution, City of Asylum, whose mission is to assist and advocate for persecuted writers and other artists. It hosts the largest residency program in the world for writers living in exile under threat of persecution or worse: death. The goal of this Grand Challenge Seminar is (1) to familiarize students with today's plight of refugees (e.g., social, political, economic factors; cross-cultural comparisons; dynamics of class, race, gender, and nationality), and (2) introduce them to a variety of textual (literary and theoretical) and visual materials and to the resources available through City of Asylum. Through readings, discussions, guest speakers, short papers, and group film projects/presentations, students will examine the ways in which writers, filmmakers, musicians, and other artists have addressed exile and migration in their work by constructing, revising, and reinventing images and cultures of the homeland. Students will explore a variety of texts (e.g., films, documentaries, art, music, photography; prose, poems, and presentations by exiled artists; archival materials; news reports, articles) and meet with and interview exiled writers and other artists.

66-145 DC First Year Seminar: Appalachia: Development, Decline, and Identity in America

Spring: 9 units

The Appalachian region, which stretches from Georgia to New York's southern tier, has a particular place in American history and memory. This course will examine the political, literary, economic, and historical narratives that surround the region, as well as examining the role that Appalachia can play as a model for developing regions in other parts of the world. The paradoxes of Appalachia have confronted American culture since its first settlement by Europeans in the 18th century: a region of unparalleled biodiversity, it has nevertheless been characterized by ongoing poverty and isolation. Politically, it has given rise to both progressive collective action and conservative rhetoric. Economically, its natural resources have been widely exploited by outside economic and industrial interests. Its inhabitants have been characterized as either fiercely independent or widely dysfunctional, giving rise to the archetypes of Mountaineers, Rednecks, or Hillbillies. Its cultural ethos has resisted ready inclusion into mainstream culture. This course will examine these paradoxes by utilizing history, literature, and public policy documents that detail the ongoing debates surrounding Appalachian development, while consulting with several invited writers, political figures, and artists who have interpreted the region's role in American history.

66-148 Introduction to Community Engagement

Intermittent: 3 units

This course is designed to prepare students to actively and thoughtfully engage in their community. Students will evaluate various models for community engagement and community-based leadership and examine ethical and social justice issues related to college and university involvement in the community. Through course discussions and direct engagement with community leaders, students will develop the ability to consider multiple perspectives, demonstrate cultural humility and critically reflect to make meaning from experiences. Students will create a plan to infuse community engagement into their academic journey that aligns with their values. This is part of the Dietrich College Community Engagement Fellowship and is only open to students that have been accepted into the program.

66-195 Documenting Israeli and Palestinian Food Cultures: Teaching and Travel

Spring: 9 units

How does the study of food cultures allow us to approach cultural intersections, conflict, and peacemaking, especially in a region as fraught as Israel and Palestine? This course, cotaught by CMU faculty in the departments of History, Modern Languages, and the Entertainment Technology Center, is designed to provide students with a historical and cultural background about the hybrid nature of Jewish and Palestinian-Arab cultures and the multiple ethnic contributions to food cultures in Israel/Palestine, as well as with media-tech skills, with the aim of preparing them for travel to Israel and the West Bank during Spring Break 2023. In the weeks leading up to the trip, the professors will introduce students to the history, literature, film, and language(s) of the region, as well as to critical scholarship in food studies. Students will also begin developing and creating their own personal narrative experience in the media of their choice. During the trip, students will participate in documenting local food cultures through film and other media. Upon their return, they will work on the production of a collaborative multi-layered interactive documentary (iDoc) meant to capture their first-hand experiences with local and regional cuisine practices in Israel and the West Bank, and present separate small group final projects based on these experiences. Specific course themes will include: the shared history of Arabs and Jews from the rise of Islam to Al-Andalus (Muslim Spain) and the Ottoman Empire to the modern and contemporary history of the Arab-Israeli conflict; the history of Sephardi, Ashkenazi, and Mizrahi Jewish immigration and contributions to Israeli cuisine; Palestinian identity, culinary traditions and gendered aspects of food practices; the politics of food; and Palestinian and Jewish voices in literary contexts. To apply to be considered for this course, go to <https://forms.gle/UbixDaA9xCBhNaoP8>

Course Website: <https://forms.gle/UbixDaA9xCBhNaoP8> (<https://forms.gle/UbixDaA9xCBhNaoP8>)

66-204 Film Festival

Spring

Students will take on the project of planning and managing a film festival that draws a college- and city-wide audience. Students will collaborate on all aspects of the festival: selecting films, generating and distributing marketing materials, designing and scheduling events, arranging facilities and general logistics, coordinating internal and external public relations, organizing fundraisers, rallying the local communities - in short, all the aspects involved in making the event a spectacular/sensational success! A unique feature of this course-cum-festival will be several directors' participation as guest speakers on the festival theme and other issues informing their films. Previous Film Festivals have covered such topics as: Democracy, Mechanization, Realism, Globalization, Migration, Media and Work. This course is also designed to supplement the study of film with the historical, political and sociological background that students need for critically analyzing the images and ideologies they see on the screen and understand how those images effect our views of the past and present time. NOTE: Interview with course instructor required prior the registration.

66-215 The Innovation Trials

Fall: 9 units

This course will examine some of the most influential intellectual property court battles throughout history and their impact on innovation. This course is geared toward students curious about Americas industrial development and interested in the political and business strategies behind the greatest innovations and technological advances of the past several centuries. The course will answer the who, what, where, when, why and how of a number of legal cases involving various technologies and areas of innovation and place them in their historical context.

66-216 Connecting with the Pittsburgh Community

Spring: 6 units

This course is designed to engage students in an exploration of various communities within the Pittsburgh area. Students will examine the ways that local organizers have been able to effectively promote positive social change. Students will develop the ability to honor the histories of diverse communities in the region while learning about the communities and the ingredients of successful communities. This course is part of the Dietrich College Community Engagement Fellowship and is only open to students who have been accepted into the program.

Prerequisite: 66-148

66-221 Topics of Law: Introduction to Intellectual Property Law

Intermittent: 9 units

This course provides students with an overview of patent, trademark, copyright, and trade secret laws. Goals for the course include identifying intellectual property (IP) rights and understanding how to take the necessary steps to protect and enforce those rights. Many recent developments in IP law will also be covered.

66-225 Politics, Persuasion, and the Press

Intermittent: 6 units

This course, conducted in the wake of a brutal presidential election, an assault on the Capitol, and a second impeachment, is intended to examine American politics and to look at how the political system in the United States and its interchange with the press shape the process of making policy. It is one part history, one part political science, one part policy studies, with special emphasis on local and national politics. In this course, students will be exposed to the 18th century Constitutional origins of the American political system as well as the 21st century implications of the American political system in the context of political upheaval in a country that, until recently, cultivated an air of stability. Through challenging readings, guest speakers, and yeasty class conversation, this course is intended to provide insights into the political system of the preeminent power in North America and, even now, around the world. In addition to the course readings alluded to below, students will be expected each day to have read in detail the Post-Gazette and either The Wall Street Journal or The New York Times, plus websites of your choice. (Rationale: Even in the Internet age, it remains the case that, in the United States, when one person involved in politics and government encounters another by 9 AM, each will have assumed of the other that they have read both The Journal and The Times.)

66-236 Introduction to Environmental Ideas

Fall and Spring: 9 units

By recognizing that environmental problems are themselves complex and require insights from both scientific and social perspectives, the University-wide Minor in Environmental Studies urges students to gain proficiency in different disciplinary habits of thinking about environmental problems. This course fulfills a requirement for the University-wide Minor in Environmental Studies. This course will introduce students from any undergraduate major at CMU to key methods and approaches for inquiry in the framework of Environmental Studies. Students will build up their ability to recognize and apply diagnostic criteria; understand key principles and terms; and take part in an informed discussion about ways of seeing, and creating interventions for environmental problems as social and scientific challenges. There are no pre-requisites for this course. Students will develop skills and apply concepts to different scenarios of environmental crisis. Preference for course registration goes to students already declared for the Minor in Environmental and Sustainability Studies.

66-300 Using Collective Leadership to Pursue Community Goals

Fall: 6 units

This course serves as the third required course in the Dietrich College Community Engagement Fellowship. This course is designed to further prepare students to actively and thoughtfully engage alongside a community focusing on a topic of the students choice. This course will bring together prior topics of cultural humility, asset-based framing, cultural competence, and community-based leadership models alongside additional topics (such as collective leadership, tailored community-focused communication, among others) responsive to their community-based learning experiences. This will prepare students to narrow their focus on a topic and community in preparation for their capstone project. Prerequisites: 66-216 and 66-148

66-307 Independent Study

All Semesters

This course is intended for students with a special interest in an interdisciplinary area in the humanities and/or social sciences not covered by a normal course. Readings and other works are developed by the student and an individual faculty member. The number of units will be assigned at the time of registration based on the number of hours to be completed (decided in advance with the sponsoring faculty member).

66-310 Internship

All Semesters: 10 units

Internships-for-credit allow students to apply course-based knowledge in a non-classroom setting, under joint supervision and evaluation by an on-site supervisor and a faculty sponsor. Approved internships must conform to college guidelines for internships-for-credit, and are available by permission only arranged through the Associate Dean's Office in Baker Hall 154.

66-320 Internship

All Semesters

Internships-for-credit allow students to apply course-based knowledge in a non-classroom setting, under joint supervision and evaluation by an on-site supervisor and a faculty sponsor. Approved internships must conform to college guidelines for internships-for-credit, and are available by permission only arranged through the Associate Dean's Office in Baker Hall 154.

66-400 Dietrich College Senior Honors Colloquium

Fall: 1 unit

The purpose of this course is to provide students admitted to the Dietrich College Senior Honors Program with a shared set of intellectual and practical sessions that will enhance their senior honors thesis experience. The course will consist of seven bi-weekly 80-minute meetings. Each will be organized around a theme and related topics that are relevant to the senior honors thesis experience, and that take advantage of both the high caliber and interdisciplinary diversity of the course members. Guest visitors will also be a common feature of the course. Topics could include: the meaning(s) of "honors;" getting started and keeping pace: the ebb and flow of an independent research project (including how to recognize and avoid procrastination; forging a successful relationship with your thesis advisor - the myth of the separation of research from writing; writing for publication); ethics in research; "interdisciplinarity," or the "unity of knowledge;" funding for research; preparing for and delivering effective presentations; intellectual property rights, and human subjects policy. Guest speakers invited to address and engage class members in discussion/debate of topics that lend themselves to interdisciplinary discussion and debate (e.g., stem cell research, which calls into play science, ethics, etc.). Course requirements will include mandatory attendance, occasional readings (where appropriate), acting as co-leader for at least one session, and - at course's end - (a) a written, formal preliminary thesis statement and action plan, endorsed by the thesis advisor, and tentatively, (b) a brief oral presentation of the thesis statement and plan to the class + thesis advisors during the last class meeting. All students will participate in critiques of fellow-students' presentations and plans.

66-402 Dietrich Leadership Development Seminar

Fall and Spring: 9 units

The Dietrich Leadership Development Seminar is for juniors and seniors in Dietrich College wishing to advance their understanding of leadership theory and practice and to develop their own skills in this regard, while creating a context for their lifelong leadership development. The course is predicated on a six pillar model proposing that ideal leaders must at once be visionary, ethical, engaging, tactical, technical - including sub-expert conversancy in realms beyond their own expertise, and reflective - including both personal mindfulness and assessment against clear metrics. In this context, the course includes a focus on strategic planning, teamwork, cultural awareness, conflict resolution, risk management, sustainability and personal welfare, professionalism, personal financial planning, and ongoing professional development. The course includes an attendance requirement and active engagement in class discussion, assigned readings/videos/podcasts (2 hours/week), self-selected experiential opportunities (2 hours/week), reflective journaling (2 hours/week), three hour-long one:ones per semester with the instructor, special guests who are leaders in various occupational and service domains, a mid-term, a final, and a final presentation. The course includes case studies and role plays to amplify the learning experience. The course is limited to twelve students, with registration based on approval of the faculty member.

66-501 Dietrich College Senior Honors Thesis I

Fall and Spring: 9 units

This is the first semester of a two-semester sequence that culminates in an original, year-long independent research or creative project. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis

Course Website: <http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html> (<http://www.cmu.edu/dietrich/undergraduate/programs/shp/>)

66-502 Dietrich College Senior Honors Thesis II

Fall and Spring: 9 units

This is the second semester of a two-semester sequence that is the culmination of an original, year-long independent research or creative project. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis

Prerequisite: 66-501

Course Website: <http://www.cmu.edu/dietrich/undergraduate/programs/shp/index.html> (<http://www.cmu.edu/dietrich/undergraduate/programs/shp/>)

66-503 Dietrich College Senior Honors Thesis

All Semesters: 18 units

This course is a one-semester alternative to the two-semester Dietrich College Senior Honors Thesis sequence 66-501/66-502. The course is open only to students who have been approved for entry into the Dietrich College Senior Honors Program, and whose senior honors thesis project has been approved as a one-semester undertaking. Thesis topics are selected by faculty and students, and reviewed and approved through the senior honors program application process. The thesis culminates in an original independent research or creative project. Dietrich College senior honors students are also required to participate in the annual Meeting of the Minds Undergraduate Research Symposium, offering either an oral presentation or poster session based on their senior honors thesis.

66-504 Senior Capstone I

All Semesters: 9 units

Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is the first in a two-course capstone sequence open only to seniors who have been admitted to the Dietrich College Student-Defined Program as a primary or additional major, and who choose the two-semester capstone sequence option. The second course in the sequence is 66-505, Senior Capstone II. Projects are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis based primarily on their student-defined major, the senior honors thesis fulfills the student-defined major capstone requirement.

66-505 Senior Capstone II

All Semesters: 9 units

Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is the second in the two-course capstone sequence, and is open only to seniors who have been admitted to the Dietrich College Student-Defined Program as a primary or additional major, and who have chosen the two-semester capstone option. The first course in the sequence is 66-504, Senior Capstone I. Projects are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis based primarily on their student-defined major, the senior honors thesis fulfills the student-defined major capstone requirement.

66-506 Senior Capstone

All Semesters: 9 units

Dietrich College student-defined majors (primary or additional) must complete a senior capstone project for at least 9 units (in one semester), or 18 units usually spread across both semesters of the senior year. The capstone project culminates in an original independent research or creative project that draws on all of the strands of the student's particular student-defined program. This course is a one-semester option for student-defined majors who propose a 9-unit/one-semester capstone project; it is also an 18-unit/one-semester alternative to the two-semester Senior Capstone sequence (66-504/66-505) for Dietrich College student-defined majors who choose the 18-unit capstone option, but who are unable to spread these units across both semesters of the senior year. The course is open only to seniors who have been admitted to the Dietrich College Student-Defined Program as either a primary or additional major. Projects and unit values are proposed by eligible students, and must be approved by a member of the faculty who agrees to be the project's primary advisor, as well as by the Dietrich College Student-Defined Program Director. These approvals must be secured no later than registration week of the semester prior to the start of the student's senior year. NOTE: For Dietrich College student-defined majors (primary or additional) who are accepted into the Dietrich College Senior Honors Program and who successfully complete a senior honors thesis, the senior honors thesis fulfills the student-defined major capstone requirement.

65-203 Applied Quantitative Social Science II

Spring: 9 units

Applied Quantitative Social Science II is the second course in the QSSS core sequence. Conducted in a seminar format, the course will feature guest lectures from a series of faculty at CMU. Students will discuss ongoing research across the social sciences, and over the course of the semester will develop a research project proposal. Seminar participation is limited to QSSS students.

General Dietrich College Courses

65-198 Research Training: History

Intermittent: 9 units

For Fall 2021: The Pittsburgh Queer History Project The Pittsburgh Queer History Project (PQHP) is an ongoing research effort to collect and catalog archival material that document the experiences of LGBTQ people in Pittsburgh and its environs from the second half of the 20th century to the present. The PQHP is co-directed by Prof. Tim Haggerty, the Director of the Humanities Scholars Program and Dr. Harrison Apple, a BXA graduate of Carnegie Mellon who received a doctorate degree from the University of Arizona in 2021, studying with the noted trans scholar Susan Stryker. Students will meet with community activists, learn how to conduct community outreach, organize archival material, and help formulate research questions based on these documents. There is no prior experience needed. The Dietrich College research training program is open to second-semester first-year students and sophomores with a 3.0 QPA or by petition. By permission of the relevant professor and the Director of Undergraduate Studies. Students sign up for these courses through both the History Department and the Dietrich College Dean's Office.

65-200 Applied Quantitative Social Science I

Fall: 9 units

The first course in the QSSS core sequence provides a fast-paced introduction to a range of methods in the quantitative social sciences. Organized around a set of case studies, the course introduces the language and methods of empirical research through a combination of seminar-style discussions of academic papers, and hands-on lab work using the statistical software R. Students will replicate results from a high-profile labor market discrimination paper, explore agent-based models of neighborhood segregation, and scrape Wikipedia data to examine imbalances in gender representation. Enrollment restricted to QSSS students.

65-201 Humanities Scholars III

Fall: 9 units

Fall 2021: Modern Love As an emotional state love is central to the human experience, whether it is the bonding that occurs between parents and their children, the camaraderie that happens between friends, colleagues, or compatriots, or the romantic attachments that occur between partners. In the modern era, love underwent a transformation: children became more precious, comradeship was reexamined and romance assumed a preeminent place in psychology, legal theory, and social organization. None of this was immutable or unchanging. This class, utilizing fiction, social science and other media, will examine the manner in which love has transformed over time and the consequences that these changes have had upon our understanding of personal interactions, sexualities, and conceptions of health, wellness and social order.

Prerequisite: 65-102

Course Website: <http://www.hss.cmu.edu/hsp/>

Heinz College of Information Systems and Public Policy

Ramayya Krishnan, Dean
Location: 1003 Hamburg Hall
www.heinz.cmu.edu (<http://www.heinz.cmu.edu>)

The next generation of leaders must deeply understand this critical point of intersection: People, policy, and technology. The connections between the three define our time, and will continue to shape the future of humankind.

At Heinz College, we've understood this since our founding, and we provide students with a foundation of data analytics, technology, evidence-based management, and rich experiential learning in contexts that are crucial to society, such as public policy, health care, information systems, cybersecurity, the arts, and entertainment.

Our research programs are best described as data-intensive social science. Our economists, statisticians, operations researchers, computer scientists, and management experts sit side by side, collaborating constantly and not sitting in traditional departmental silos. For this reason, they are able to approach complex societal problems in an altogether different way and impart this interdisciplinary mindset to our students.

The unique co-location of our two schools, the School of Public Policy and Management (<https://www.heinz.cmu.edu/about/public-policy-management/>) and the School of Information Systems and Management (<https://www.heinz.cmu.edu/about/information-systems-management/>), offers opportunities for collaboration that simply cannot be duplicated elsewhere. We also offer two groundbreaking Joint Degree Programs with the CMU College of Fine Arts (<https://www.heinz.cmu.edu/about/fine-arts/>).

Graduates of Heinz College are highly sought by employers across sectors for their interdisciplinary expertise and ability to use relevant data to solve complex problems. Our alumni work for government agencies at the federal, state, and local levels. They work in roles that directly impact national security. They work for tech giants, big consulting firms, major media outlets, cultural institutions, top hospitals and health systems, non-profits, and community organizations of all sizes. They work for startups—or they found their own.

Learn more about Heinz College graduate degree programs (<https://www.heinz.cmu.edu/programs/>).

Public Interest Technology

Public Interest Technology (PIT) is an emerging field unto itself, but Carnegie Mellon University has been a leader in this space for over 50 years, promoting the use of technology to advance the public interest. Continued excellence in this space is a priority for Heinz College.

Learn more about PIT at Heinz College (<https://www.heinz.cmu.edu/about/public-interest-technology/>).

Minor in Decision Analytics and Systems (DAS)

Students in any undergraduate major at Carnegie Mellon University can elect the Minor in Decision Analytics and Systems (DAS), building along the way a robust interdisciplinary toolkit that draws on computer science, economics, statistics, operations research, machine learning, and information systems. You will also learn how-to apply this toolkit to consequential societal problems!

Heinz College offers the undergraduate **Minor in Decision Analytics and Systems (DAS)**, providing you with the opportunity to add systems thinking and evidence-based problem solving to any field of study.

Data is a means to an end—creating value for people and society. But before data can create value, there comes a critical decision point. DAS prepares you to be the one who makes that decision, navigating the process from end to end: from identifying a current decision point and the problem it could solve, to determining the right decision and its potential value, and finally communicating that value and putting the decision into action.

Using Heinz College's deep expertise in analytics, public policy and information systems as a launchpad, the DAS minor features gamechanging experiential courses that ground DAS strategies in real world application, so you can see the social impacts of this work firsthand.

For more information, contact Professor Raja Sooriamurthi
at raja@cmu.edu.

DAS MINOR CURRICULUM AND COURSEWORK

DAS Core Courses:

- Introduction to DAS (94-416 Introduction to Decision Analytics and Systems)
- Simulation for DAS (94-417)
- Optimization for DAS (94-433 Optimization for DAS)
- Applied Econometrics for DAS (94-431 Applied Econometrics for DAS)
- Critical Analysis of Policy Research (90-440 Critical Analysis of Policy Research)
- Machine Learning for Public Policy Lab (94-489 Machine Learning for Public Policy Lab)

Expected Pre-requisites:

- Calculus (21-111 Calculus I, 21-112 Calculus II, OR 21-256 Multivariate Analysis)
- Matrix Algebra (21-240 Matrix Algebra with Applications)
- Computer Science (15-112 Fundamentals of Programming and Computer Science AND 15-122 Principles of Imperative Computation)
- Probability and Statistics (36-225 Introduction to Probability Theory AND 36-226 Introduction to Statistical Inference)
- Principles of Microeconomics (73-102 Principles of Microeconomics)

SAMPLE SCHEDULE: DAS

*Below is one possible schedule for the **DAS minor**. Actual schedules may vary based on course availability and other factors.*

Year Two - Fall Semester

- Introduction to DAS
- Optimization for DAS

Year Two - Spring Semester

- Simulation for DAS
- Applied Econometrics for DAS

Year Three - Fall Semester

- Critical Analysis of Policy Research

Year Three - Spring Semester

- Machine Learning for Public Policy Lab

Minor in Health Care Policy and Management

Sponsored by:

Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:

Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new

demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:

| | | |
|--------|--|---|
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 90-436 | Health Systems | 6 |
| 90-472 | Health Policy | 6 |

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses

| | | |
|--------|--|----|
| 94-409 | Healthcare Information Systems | 12 |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 90-834 | Health Care Geographical Information Systems | 12 |

Other courses as approved

Humanities and Social Sciences Courses (9 units each)

| | | |
|--------|--|---|
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 42-444 | Medical Devices | 9 |

Other courses as approved

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

| | | |
|--|---------------------------|-------|
| Health Management/Administration Focus | | Units |
| 90-832 | Health Law | 6 |
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |

| | | |
|---------------------|--|-------|
| Health Policy Focus | | Units |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 88-365/90-882 | Behavioral Economics and Public Policy | 9 |

Other courses as approved

| | | |
|-----------------------------|--|-------|
| Health Analytics & IT Focus | | Units |
| 94-409 | Healthcare Information Systems | 12 |
| 90-834 | Health Care Geographical Information Systems | 12 |
| 42-444 | Medical Devices | 9 |

Other courses as approved

Five-Year (Accelerated) Master's Programs

Students with the drive to develop as leaders and enter the job market more quickly can earn their CMU undergraduate degree **and** a professional master's degree from Heinz College together in five years instead of the typical six.

An Accelerated Master's Program (AMP) isn't just a savings of time. It's also a considerable savings in cost, and adds a tremendous level of experience and expertise in a specific industry.

In the Heinz College AMP program, students complete 3 years in a CMU undergraduate program (any major), followed by 1 year of integrated study, followed by 1 full year at Heinz College.

The following Heinz College master's degree programs offer accelerated options for CMU undergraduates:

- Master of Arts Management (MAM)
- Master of Entertainment Industry (MEIM)*
- Master of Information Systems Management (MISM)
- Master of Science in Health Care Policy and Management (MSHCPM)
- Master of Science in Information Security Policy and Management (MSISPM)
- Master of Information Security Policy and Management (MSISPM)
- Master of Science in Public Policy and Management (MSPPM)*

Students must apply and be admitted to Heinz College. Learn more about Heinz College admissions requirements (<https://www.heinz.cmu.edu/admissions/>).

For more information on Accelerated Master's Programs, please contact the Heinz College Office of Admissions at hznadmit@andrew.cmu.edu or by phone 412-268-2164.

***Note on AMP planning for MEIM and MSPPM - Washington, D.C.:** Due to the rigorous format and unique academic demands of the MEIM and MSPPM - Washington D.C. programs—with their second years at CMU's Los Angeles and D.C. campuses, respectively—interested students should begin the AMP planning process as early as possible in their undergraduate career. Students must ensure that they have satisfied all requirements for their undergraduate degree, as well as their first-year master's requirements, by the end of the fourth AMP year.

Ph.D. Program

Distinguished by the interdisciplinary model of Heinz College and Carnegie Mellon University, our Ph.D. programs prepare graduates to lead change in their chosen fields through meaningful collaborations and hands-on work with our renowned and extremely accessible faculty.

Heinz College features the unique co-location of two schools: The School of Information Systems and Management and The School of Public Policy and Management; however, below that larger structure, we are a college without departments and their characteristic silos. Our faculty, students, and research centers thrive by working together to solve problems across subjects, disciplines, and business verticals.

In the Heinz College Ph.D. program, you will conduct innovative research to address increasingly complex challenges facing society, whether those challenges are technical, organizational, political, economic, social, or—as is often the case—some combination thereof.

- Ph.D. in Information Systems and Management (<https://www.heinz.cmu.edu/programs/phd-programs/information-systems-management/>)
- Ph.D. in Public Policy and Management (<https://www.heinz.cmu.edu/programs/phd-programs/public-policy-management/>)
- Joint Ph.D. Programs (<https://www.heinz.cmu.edu/programs/phd-programs/joint-phd/>)
- Recent Ph.D. Placements (<https://www.heinz.cmu.edu/programs/phd-programs/phd-placements/>)

Contact:

Martin S. Gaynor, Ph.D., Program Director
4800 Forbes Avenue
Hamburg Hall 2217
Pittsburgh, PA 15213
412-268-7933
mgaynor@andrew.cmu.edu

Faculty and Research Centers

FACULTY

Heinz College has an international reputation for the quality of its research. Our interdisciplinary environment creates exciting opportunities for collaboration and produces a breadth of research work not typically found in schools of our size.

Our faculty and research centers consistently receive funding support from government agencies, foundations and corporate partners, like the National Science Foundation; the Heinz Endowments; the Mellon Foundation; the

U.S. Departments of Defense, Commerce, Health and Human Services, and Housing and Urban Development; the Sloan Foundation; and the National Institute of Justice.

Visit our Faculty pages (<https://www.heinz.cmu.edu/faculty-research/>) to learn more about individual faculty members, accomplishments, and current research.

RESEARCH CENTERS

We host, or are closely associated with, these CMU research centers:

- Arts Management and Technology Laboratory (AMTLab) (<http://amt-lab.org/>)
- Block Center for Technology and Society (<https://www.cmu.edu/block-center/>)
- Center for Behavioral Decision Research (CBDR) (<http://cbdr.cmu.edu/>)
- Center for Economic Development (CED) (<https://www.heinz.cmu.edu/ced/>)
- CyLab (<http://www.cylab.cmu.edu/>)
- Event and Pattern Detection Lab (EPD Lab) (<http://epdlab.heinz.cmu.edu/>)
- iLab (<http://ilab.heinz.cmu.edu/>)
- Initiative for Digital Entertainment Analytics (IDEA) (<http://idea.heinz.cmu.edu/>)
- Living Analytics Research Centre (LARC) (<https://larc.smu.edu.sg/>)
- Metro21: Smart Cities Institute (<https://www.cmu.edu/metro21/>)
- Privacy Economics Experiments (PEEX) Lab (<https://peex.heinz.cmu.edu/>)
- Program for Research and Outreach on Gender Equity in Society (PROGRESS) (<https://www.cmu.edu/dietrich/progress-equity-leadership/>)
- Risk and Regulatory Services Innovation Center (sponsored by PwC) (<https://www.cmu.edu/risk-reg-center/>)
- Traffic21 (<https://traffic21.heinz.cmu.edu/>)

Diversity and Inclusion

The Heinz College of Information Systems and Public Policy represents over 50 nations and over 40 U.S. states, which increases our ability to foster a community with greater variation in perspectives and approaches to our work.

By design, Heinz College is an empathetic and open environment that inspires continuous learning, conversation, and intelligent action that will impact society for the better.

Diversity, inclusion, and equity are not radical concepts. Rather, the ongoing pursuit of these ideals is fundamental to the energetic exchange of ideas; the success of our students, faculty, and staff; and the unlocking of innovations that will improve the human condition.

Heinz College proudly champions the unique experiences of all members of our campus community. It is a priority for Heinz College to attract, maintain, and nurture a student body of diverse viewpoints, backgrounds, and talents. We are also committed to improving access to our graduate programs, in particular for underrepresented populations. We support these efforts through a variety of initiatives, programming, and partnerships in addition to Carnegie Mellon University's campus-wide efforts.

Learn more about Diversity & Inclusion at Heinz College (<https://www.heinz.cmu.edu/about/diversity/>).

CONTACT

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Heinz College of Information Systems and Public Policy
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Pittsburgh, PA 15213

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www.heinz.cmu.edu (<http://www.heinz.cmu.edu>)

Faculty

ALESSANDRO ACQUISTI, Assistant Professor of Information Systems and Public Policy – Ph.D., UC Berkeley; Carnegie Mellon, 2003–

LEMAN AKOGLU, Dean's Associate Professor of Information Systems – Ph.D., Computer Science, Carnegie Mellon University; Carnegie Mellon, 2012–

LINDA BABCOCK, James M. Walton Professor of Economics – Ph.D., University of Wisconsin at Madison; Carnegie Mellon, 1988–

EDWARD BARR, Associate Teaching Professor – M.S., Indiana University of Pennsylvania; Carnegie Mellon, 2000–

MARTIN BARRETT, Associate Teaching Professor – Ph.D. in Computer Science, University of Wisconsin-Madison;

DAREEN BASMA, Assistant Dean of Diversity, Inclusion, Climate & Equity (DICE) – Bachelor's degree in Psychology & Religious Studies, Master's degree in Mental Health Counseling, Ph.D. in Counselor Education & Supervision, University of Tennessee;

ELI BEN-MICHAEL, Assistant Professor – PhD in Statistics, U.C. Berkeley;

ALFRED BLUMSTEIN, J. Erik Jonsson University Professor of Urban Systems and Operations Research; Director, National Consortium on Violence Research – Ph.D., Cornell University; Carnegie Mellon, 1969–

SILVIA BORZUTSKY, Associate Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 2001–

LEE BRANSTETTER, Associate Professor of Economics – Ph.D., Harvard University; Carnegie Mellon, 2006–

JONATHAN CAULKINS, Professor of Operations Research and Public Policy; Faculty Chair, Master of Public Policy and Management Program – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1990–

GEORGE CHEN, Assistant Professor of Information Systems – Ph.D. in Electrical Engineering and Computer Scienc, MIT; Carnegie Mellon, 2015–

DAVID CHOI, Assistant Professor of Statistics and Information Systems – Ph.D, Electrical Engineering, Stanford University; Carnegie Mellon, 2004–

ALEXANDRA CHOULDECHOVA, Assistant Professor of Statistics and Public Policy – Ph.D. Statistics, Stanford University; Carnegie Mellon, 2014–

JACK CHOW, Distinguished Service Professor – M.D., University of California at San Francisco School of Medicine; Carnegie Mellon, 2011–

KAREN CLAY, Assistant Professor of Economics and Public Policy – Ph.D., Stanford University; Carnegie Mellon, 1997–

BRETT ASHLEY CRAWFORD, Associate Teaching Professor of Arts Management – Ph.D. in Theatre History and Criticism, University of Maryland;

GEORGE T. DUNCAN, Professor of Statistics, Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 2011–

NEELAM DWIVEDI, Assistant Teaching Professor – PhD in Information Sciences and Technology, Penn State University;

PEDRO FERREIRA, Associate Professor of Information Systems – PhD, Engineering and Public Policy Specialization in Telecom Policy, Carnegie Mellon University; Carnegie Mellon, 2004–

REBEKAH FITZSIMMONS, Assistant Teaching Professor of Professional Communication – PhD in English, University of Florida;

MARTIN GAYNOR, E.J. Barone Professor of Economics and Health Policy; Faculty Chair, Ph.D. Program – Ph.D., Northwestern University; Carnegie Mellon, 1995–

RAYID GHANI, Distinguished Career Professor – Machine Learning, Carnegie Mellon University;

WILLIAM GOGOLAK, Assistant Teaching Professor – PhD in Finance, Illinois Institute of Technology;

GABRIELA GONGORA-SVARTZMAN, Assistant Teaching Professor of Information Systems – PhD in Engineering Management, Stevens Institute of Technology, School of Systems and Enterprises;

CHRISTOPHER GORANSON, Distinguished Service Professor – Master of Geographic Information Systems, Penn State University;

WILPEN GORR, Professor of Public Policy and Information Systems – PhD, Operations Research, Carnegie Mellon University;

COREY HARPER, Assistant Professor of Civil and Environmental Engineering – BS in Civil Engineering, MS and PhD, Morgan State University, Carnegie Mellon University;

AMELIA HAVILAND, Professor of Statistics and Health Policy – PhD, Statistics and Public Policy, Carnegie Mellon University;

KIM J. HYATT, Associate Teaching Professor

AKSHAYA JHA, Assistant Professor of Economics and Public Policy – Ph.D. in Economics, Stanford University;

- JAMES F. JORDAN, Distinguished Service Professor – M.B.A., Boston University; Carnegie Mellon, 2011–
- MARK S. KAMLET, Provost, CMU, and H. John Heinz III Professor of Economics and Public Policy – Ph.D., University of California at Berkeley; Carnegie Mellon, 1978–
- FELIX KOENIG, Assistant Professor of Economics – Ph.D. and MSc in Economics, London School of Economics;
- BRIAN KOVAK, Associate Professor of Economics and Public Policy – Ph.D., Economics, University of Michigan;
- DAVID KRACKHARDT, Professor of Organizations and Public Policy – Ph.D., University of California at Irvine; Carnegie Mellon, 1991–
- RAMAYYA KRISHNAN, William W. and Ruth F. Cooper Professor of Management Science and Information Systems; Faculty Chair, Master of Information Systems Management Program – Ph.D., University of Texas at Austin; Carnegie Mellon, 1987–
- KRISTIN KURLAND, Associate Teaching Professor (joint with School of Architecture) – B.A., University of Pittsburgh; Carnegie Mellon, 1999–
- CHRIS LABASH, Assistant Teaching Professor
- DAVID LASSMAN, Distinguished Service Professor of Organizational Management – BS, Mechanical and Aerospace Engineering, MBA, Princeton University, Harvard Business School;
- GORDON LEWIS, Associate Professor of Sociology; Faculty Chair, Master of Public Management Program – Ph.D., Stanford University; Carnegie Mellon, 1969–
- BEIBEI LI, Associate Professor of IT and Management – PhD in Information Systems, Stern School of Business, New York University;
- ARI LIGHTMAN, Practice Professor, Digital Media and Marketing – M.B.A., Carnegie Mellon University; Carnegie Mellon, 2011–
- PETER MADSEN, Senior Lecturer in Ethics and Public Policy – Ph.D., Duquesne University; Carnegie Mellon, 1988–
- DAN MARTIN, Director, Master of Arts Management Program, and Associate Professor (College of Fine Arts) – M.F.A., Brooklyn College/City University of New York; Carnegie Mellon, 1993–
- HAYLEE MASSARO, Assistant Teaching Professor
- ANNA MAYO, Assistant Professor of Organizational Behavior – PhD in Organizational Behavior & Theory, Carnegie Mellon's Tepper School of Business;
- MICHAEL MCCARTHY, Associate Teaching Professor of Information Systems Management – M.S., University of Pittsburgh; Carnegie Mellon, 1999–
- SARAH MENDELSON, Distinguished Service Professor of Public Policy and Head of Heinz College in Washington, DC – PhD in Political Science, Columbia University;
- JOE MERTZ, Associate Teaching Professor – Ph.D., Carnegie Mellon; Carnegie Mellon, 1994–
- DANIEL NAGIN, Theresa and H. John Heinz III Professor of Public Policy, and Research Director, National Consortium on Violence Research – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1979–
- REMA PADMAN, Professor of Operations Research and Information Management; Faculty Chair, Master of Science in Health Care Policy and Management Program – Ph.D., University of Texas at Austin; Carnegie Mellon, 1989–
- SEAN QIAN, Henry Posner, Anne Molloy, and Robert and Christine Pietrandrea Associate Professor of Civil Engineering; Director, Mobility Data Analytics Center (MAC) – PhD, University of California Davis;
- SETH RICHARDS-SHUBIK, Assistant Professor of Economics and Public Policy – Ph.D., University of Pennsylvania; Carnegie Mellon, 2011–
- DAVID RIEL, Distinguished Service Professor – Ph.D. ABD in Education, West Virginia University;
- STACY ROSENBERG, Associate Teaching Professor – MA in Media, Culture, and Communication, New York University;
- DENISE ROUSSEAU, H. J. Heinz II Professor of Organizational Behavior (joint with Graduate School of Industrial Administration) – Ph.D., University of California at Berkeley; Carnegie Mellon, 1994–
- ANANYA SEN, Assistant Professor of Information Technology and Management – Ph.D in Economics, Toulouse School of Economics;
- EDSON SEVERNINI, Associate Professor of Economics and Public Policy – Ph.D., Economics, University of California at Berkeley; Carnegie Mellon, 2013–
- MICHAEL SMITH, Assistant Professor of Information Technology – Ph.D., Alfred P. Sloan School of the Massachusetts Institute of Technology; Carnegie Mellon, 2000–
- RAJA SOORIAMURTHI, Teaching Professor Information Systems Program, Director Decision Analytics and Systems minor
- RICHARD STAFFORD, Distinguished Service Professor – M.S., Public Policy and Management, Carnegie Mellon University; Carnegie Mellon, 2005–
- DAVID STEIER, Distinguished Service Professor – Doctor of Philosophy (PhD) in Computer Science, Carnegie Mellon University;
- JILLIAN STEPHENSON, Assistant Teaching Professor; Certified Public Accountant – Bachelor of Science in Business Administration, Accounting, University of Pittsburgh;
- ROBERT STRAUSS, Professor of Economics and Public Policy; Faculty Chair, Master of Science in Educational Technology Management Program – Ph.D., University of Wisconsin; Carnegie Mellon, 1979–
- LAURA SYNNOTT, Associate Teaching Professor, Healthcare Policy and Management – M.S., Health Services Administration, University of Michigan; Carnegie Mellon, 2004–
- JANUSZ SZCZYPULA, Associate Teaching Professor in Information Systems – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–
- JOEL TARR, Richard S. Caliguiri Professor of Urban and Environmental History and Policy – Ph.D., Northwestern University; Carnegie Mellon, 1967–
- LOWELL TAYLOR, Professor of Economics and Public Policy; Associate Dean of Faculty – Ph.D., University of Michigan; Carnegie Mellon, 1990–
- RAHUL TELANG, Assistant Professor of Information Systems – Ph.D., Carnegie Mellon; Carnegie Mellon, 2001–
- JEREMY WEISS, Assistant Professor of Health Informatics – MD, PhD, University of Wisconsin;
- PETER ZHANG, Assistant Professor of Operations Research – Ph.D. in Engineering Systems, Massachusetts Institute of Technology;
- SHIXIANG ZHU, Assistant Professor of Data Analytics – Ph.D. in Machine Learning, Georgia Institute of Technology; Carnegie Mellon, 2022–

Mellon College of Science

Curtis Meyer, Interim Dean

Maggie Braun, Associate Dean for Undergraduate Affairs

Kenneth Hovis, Assistant Dean for Educational Initiatives

Location: Doherty Hall 1324
www.cmu.edu/mcs (<http://www.cmu.edu/mcs/>)

The Mellon College of Science (MCS) has provided the undergraduate training for many of today's leading scientists. We have earned national recognition for our integration of undergraduate education and research from such organizations as the National Science Foundation, the Howard Hughes Medical Institute, and the Beckman Foundation. MCS students gain a broad education in science, mathematics, and the liberal arts while using state-of-the-art computational approaches in their courses, laboratories, and research activities. Our faculty members are committed to teaching as well as to a wide range of scientific research. This combined emphasis on education and research brings special benefits to students, including increased awareness of current scientific developments that are incorporated in classroom instruction, and, most importantly, opportunities to participate with faculty, graduate students, and other research scientists in a variety of research projects.

In the context of rigorous training in each field, the MCS curriculum emphasizes problem-solving, communication, and analytical skills, and it teaches our students the value of hard work and discipline. Our students go on to highly successful careers in a broad range of fields like astrophysics, biotechnology, computer science, business management, environmental science, health care policy, investment banking, marketing analysis, medicine, patent law, and pharmaceuticals. Our alumni credit their education in science for preparing them for a lifetime of learning and achievement; their employers attest to their ability to succeed and to continue learning in an ever-changing world.

The MCS Departments of Biological Sciences, Chemistry, Mathematical Sciences, and Physics each outline their degree programs and courses in the departmental sections. Students select their major in the spring of the first year so that the sophomore year begins with a focus within a department. Most of the courses required within a major are scheduled in the sophomore and junior years, leaving much of the senior year and part of the junior year open for electives. This provides the opportunity to participate in undergraduate research, explore interdisciplinary studies, study abroad, pursue additional majors or minors in other fields, or take other specialty courses oriented toward immediate job placement upon graduation or entry into graduate studies.

Science education in the 21st Century demands educational experiences that are much broader than the traditional preparation of a scholar in a chosen field of science. We want our MCS graduates to be **scholars** who are deeply trained in their discipline(s), and also **professionals** adept at communicating to broad audiences, accustomed to working in diverse, multidisciplinary teams, and keenly aware of the global context of their work. We want them to be **citizens** who are actively involved and globally engaged, and to grow as **persons** with a sense of wellness and balance.

With these ambitions in mind, we have set forth fifteen (15) outcomes that all MCS undergraduate students should complete in their time at Carnegie Mellon. Upon graduation, MCS students should be able to:

1. Apply foundational and advanced mathematical and scientific knowledge in a chosen field of study appropriately and fluently to solve complex problems, to integrate concepts across disciplines, and to adapt their knowledge to new situations.
2. Critically assess their current state of knowledge and expertise and acquire new knowledge in pursuit of both specific scientific goals and new intellectual interests broadly throughout their lifetime.
3. Communicate effectively via oral, visual, and written formats with an understanding of the perspectives and expectations of diverse audiences, including those within their chosen discipline, outside that discipline (but within STEM), and non-scientists.
4. Participate effectively in multidisciplinary research and/or other teams pursuing a shared vision while optimizing team outcomes.
5. Use the appropriate tools and required media literacy to acquire, assess, and analyze data and information from diverse sources.
6. Recognize and explain the importance of at least one current research topic in a STEM field outside of their major.
7. Recognize and explain the similarities and differences in analyzing/approaching problems, including in technical and non-technical fields other than their major.
8. Demonstrate knowledge of the arts, humanities, and social sciences.
9. Recognize the interplay of science, society, public policy, business, and economics.
10. Identify global examples of the reciprocal relationships among science, technology, political forces, societal contexts, and environmental issues.
11. Describe multiple similarities and differences between one's own culture and that of others.
12. Engage in recursive, reflective processes to assess their own levels of physical, emotional, and social wellness and then to choose activities that promote these aspects of wellness.
13. Engage in recursive, reflective processes to balance multiple endeavors by setting priorities and managing time in academic, meta-curricular, and personal dimensions.
14. Recognize ethical issues and appreciate the complexities of interrelationships among them, and the use of information in ethical and legal manners.
15. Articulate how one's own developing skills in science and technology can be increasingly used in constructive community service or engagement that recognizes the potential impact on local and global issues, including environmental impact and sustainability.

Tailoring Your Education

The Mellon College of Science offers students tremendous opportunity for tailoring their education to meet individual professional objectives. Whether you target your degree to a particular field in your discipline via departmental options and concentrations, add a secondary major, minor, or degree to your primary degree program, participate in honors programs, or pursue a master's degree along with your bachelor's degree, MCS has much to offer you. Many of these opportunities are outlined below.

Departmental Concentrations

Each department in MCS offers degrees and programs that allow students to explore particular fields within a science discipline. These are outlined below — see the departmental sections for further details.

Biological Sciences

- Biochemistry
- Biophysics
- Cell Biology
- Computational Biology
- Developmental Biology
- Genetics
- Molecular Biology
- Neuroscience

Chemistry

- Biochemistry
- Biological Chemistry
- Colloids, Polymers, and Surfaces
- Computational Chemistry
- Environmental Chemistry
- Management
- Material Chemistry
- Polymer Science

Mathematical Sciences

- Computational and Applied Mathematics
- Computational Finance
- Discrete Mathematics and Logic
- Mathematics
- Operations Research
- Statistics

Physics

- Applied Physics
- Astrophysics
- Biological Physics
- Chemical Physics
- Computational Physics
- Quantum Physics

Minors, Double Majors, and Double Degrees

As an MCS student, you can pursue additional majors and minors to complement your primary degree, not only within the science college, but also through the other colleges at Carnegie Mellon. Carnegie Mellon offers many exciting interdisciplinary majors and minors, some of which are listed below. In addition, every college and most departments have designed minors or second majors in their discipline so that you can gain expertise in their fields as well.

Some students choose to gain this expertise by following a double degree program. This results in two distinct bachelor's degrees. Please see the section on Undergraduate Academic Regulations for a more formal definition of these "Multiple Degree" programs.

Interdisciplinary Majors and Minors

Here is a sampling of just a few of the interdisciplinary minors and majors offered at Carnegie Mellon (not all are in MCS). Please see the appropriate sections elsewhere in this catalog for specific descriptions and course requirements.

- Biological Sciences and Psychology Major
- Computer Science Minor
- Engineering Studies Minor
- Environmental and Sustainability Studies Additional Major or Minor
- Environmental Policy Major
- Health Care Policy and Management Minor
- International Affairs Minor
- Mathematics and Economics Major
- Neuroscience Major and Minor
- Operations Research Minor
- Robotics Minor
- Scientific Computing Minor
- Technology and Policy Minor

For a complete list of the minors offered at Carnegie Mellon, please go to Undergraduate Options (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#minorstext>).

University Student-Defined Majors

With a well-thought proposal, you may be able to pursue a major you have designed to meet your particular interests and goals. Please see the catalog section on Student-Defined Majors (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studentdefinedmajortext>).

General Education Requirements

Students pursuing any MCS bachelor's degree will fulfill the 15 Core Education outcomes (p. 582) through their primary MCS major and by completing the following technical and nontechnical breadth requirements prior to graduation. Please see MCS Course Planning Guide (<https://www.cmu.edu/mcs/undergrad/course-planning.html>) for the recommended timeline to complete these requirements.

Technical Breadth Requirements

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing four (4) technical courses in the Science, Technology, Engineering, and/or Mathematics (STEM) fields at Carnegie Mellon University.

A student must take at least 9 units, outside of their primary major department, from each of four categories listed below. These may include prerequisite courses or courses required by their major department but must be outside their home department. AP/IB/Cambridge credit may NOT be used to fulfill these requirements. At least three of these courses must be taken in their first year. The categories are:

A. Life Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

LIFE SCIENCES

| | | |
|--------|---|----|
| 02-250 | Introduction to Computational Biology | 12 |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | 9 |
| 03-117 | Frontiers, Analysis, and Discovery in Biological Sciences | 6 |
| 03-121 | Modern Biology | 9 |
| 03-151 | Honors Modern Biology | 10 |
| 03-124 | Modern Biology Laboratory | 9 |
| 03-125 | Evolution | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 03-135 | Structure and Function of the Human Body | 9 |
| 03-161 | Molecules to Mind | 9 |
| 03-231 | Honors Biochemistry | 9 |
| | or 03-232 Biochemistry I | |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 42-202 | Physiology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

B. Physical Sciences

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

PHYSICAL SCIENCES

| | | |
|--------|---|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | 10 |
| 09-111 | Nanolegos: Chemical Building Blocks | 9 |
| 09-214 | Physical Chemistry | 9 |
| 09-217 | Organic Chemistry I | 9 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |

| | | |
|--------|--|----|
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 33-121 | Physics I for Science Students | 12 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| 33-141 | Physics I for Engineering Students | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 33-151 | Matter and Interactions I | 12 |
| 33-152 | Matter and Interactions II | 12 |
| 33-211 | Physics III: Modern Essentials | 10 |
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-225 | Quantum Physics and Structure of Matter | 9 |

C. Mathematics, Statistics, and Computer Science

(Refer to your specific department for how this category should be fulfilled. Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

MATH, STATS, and CS

| | | |
|-----------|--|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-124 | Calculus II for Biologists and Chemists | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-128 | Mathematical Concepts and Proofs | 12 |
| 21-228 | Discrete Mathematics | 9 |
| 21-241 | Matrices and Linear Transformations | 10 |
| or 21-240 | Matrix Algebra with Applications | |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| 36-200 | Reasoning with Data | 9 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 36-217 | Probability Theory and Random Processes | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 36-225 | Introduction to Probability Theory | 9 |
| 36-247 | Statistics for Lab Sciences | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

D. STEM Course

- All of the above courses
- Any introductory engineering course from CIT
- A STEM course approved by an MCS advisor

Technical Breadth-Departmental Requirements

Some of the majors in MCS require certain courses from the technical breadth requirement that are necessary for either prerequisite knowledge in the major or scientific breadth. For each of the four majors in MCS the Technical Breadth Requirement is completed as follows. If these requirements are met by AP/IB/Cambridge A Level Exams, students can choose any course from the categories to fulfill the Technical Breadth Requirement.

Biological Sciences

1. Life Sciences: any courses in this category **except** for the 03-XXX courses
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Chemistry

1. Life Sciences: 03-121 or 03-231 or 03-232
2. Physical Sciences: 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Mathematical Sciences

1. Life Sciences: any courses in this category
2. Physical Sciences: any course in this category
3. Math/CS/Stats: any course in this category **except** for the 21-XXX courses, 36-200 Reasoning with Data, or 36-202
4. STEM Elective: any STEM course from the approved list.

Physics

1. Life Sciences: 03-121
2. Physical Sciences: 09-105 or 09-111 Nanolegos: Chemical Building Blocks
3. Math/CS/Stats: 21-120, 21-122, 21-259
4. STEM Elective: will be fulfilled by courses above or any STEM course from the approved list.

Nontechnical Breadth Requirements

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following nontechnical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for MCS bachelor's degrees must complete the following nontechnical breadth requirements:

A. First Year Courses:

The following three courses must be taken in the first year:

| | | |
|-----------|---|---|
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| or 38-100 | CATALYST - MCS First-Year Seminar | |
| 76-101 | Interpretation and Argument <small>A total of nine units must be completed in order to fulfill this requirement</small> | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |
| or 76-106 | Writing about Literature, Art and Culture | |
| or 76-107 | Writing about Data | |
| or 76-108 | Writing about Public Problems | |
| 99-101 | Computing @ Carnegie Mellon | 3 |

B. Science and Society Course:

This requirement must be completed no later than the penultimate semester. Any student who finds an appropriate Carnegie Mellon course not on the pre-approved elective list below that might fulfill this requirement should contact their home department's Director of Undergraduate Studies to review the course description to determine if it can be substituted. In addition, transfer courses will also be considered for this category. However, this course requirement *cannot* be satisfied with AP/IB/Cambridge exam credit.

- Option 1: Take 38-304 Reading and Writing Science
- Option 2: Take one of the pre-approved (<https://www.cmu.edu/mcs/science-society/electives.html>)electives (<https://www.cmu.edu/mcs/science-society/electives.html>)

Note: QBS students should plan to enroll in 38-301 PROPEL in spring of junior year to fulfill this requirement.

C. ENGAGE Courses:

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness, the arts and community service. Please see the course description for information on when these courses should be taken:

| | | |
|----------------|------------------------------------|---|
| ENGAGE COURSES | | |
| 38-110 | ENGAGE in Service | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |

| | | |
|--------|-------------------------------------|---|
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |

D. Cultural/Global Understanding Course:

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their home department's Director of Undergraduate Studies to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement *cannot* be satisfied with AP/IB/Cambridge exam credit.

CULTURAL/GLOBAL UNDERSTANDING

| | | |
|--------|---|---|
| 57-173 | Survey of Western Music History | 9 |
| 57-209 | The Beatles | 9 |
| 57-306 | World Music | 9 |
| 70-100 | Global Business | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 76-217 | Literature & Culture of the 20th and 21st Century | 9 |
| 76-221 | Books You Should Have Read By Now | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-287 | Sex & Texts | 9 |
| 76-386 | Language & Culture | 9 |
| 79-145 | Genocide and Weapons of Mass Destruction | 9 |
| 79-160 | Introduction to the History of Science | 9 |
| 79-170 | Introduction to Science, Technology, and Society | 9 |
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-201 | Introduction to Anthropology | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-216 | Genghis Khan and the Mongol Empire | 3 |
| 79-220 | Screening Mexico: Mexican Cinema, 1898 to Present | 6 |
| 79-222 | China and the Second World War | 6 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-232 | Arabian Peninsula Environmental History | 9 |
| 79-234 | Technology and Society | 9 |
| 79-238 | Modern African American Film: History and Resistance | 6 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |

| | | |
|--------|---|------|
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-268 | World War I: The Twentieth Century's First Catastrophe | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-281 | Introduction to Religion | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-319 | India Through Film | 6 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-345 | Roots of Rock & Roll | 9 |
| 79-350 | Early Christianity | 9 |
| 79-355 | Fake News: "Truth" in the History of American Journalism | 6 |
| 79-375 | Science & Religion | 6 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 80-100 | Introduction to Philosophy | 9 |
| 80-101 | Dangerous Ideas in Science and Society | 9 |
| 80-130 | Introduction to Ethics | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-252 | Kant | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 82-238 | Topics in Chinese Culture | 9 |
| 82-290 | Transformative Learning through Cross-Cultural Analysis | Var. |
| 82-xxx | Any course from Modern Languages | |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-306 | Latin American Politics | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-405 | The Future of Warfare | 9 |
| 85-350 | Psychology of Prejudice | 9 |
| 85-352 | Evolutionary Psychology | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 99-3xx | Any of the Country Today courses | 3 |

E. Nontechnical Elective Courses

To fulfill this requirement, students must complete a minimum of four (4) nontechnical courses totaling at least 36 units in the College of Fine Arts, the Tepper School of Business, and/or the Dietrich College for Humanities and Social Sciences. A maximum of 18 units of these units may be fulfilled via AP/IB/Cambridge exam credit. Up to 36 units of these nontechnical elective units may be filled by transfer credit (with prior approval through the MCS transfer credit process). Courses counted toward the Cultural/Global Understanding requirement and the First-Year Writing requirement **do not** count toward this requirement.

Note: Check our web site for courses from DC, CFA, and Tepper that may NOT be used (<http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html>) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, and Heinz

College) that do satisfy (<http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html>) this requirement.

The following requirements apply to all MCS bachelor's degrees:

1. Students must complete a minimum of 360 units.
2. The four courses required for the Technical Breadth category can be completed at Carnegie Mellon or via transfer credit.
3. AP/IB/Cambridge exam credit cannot be used to fulfill the Science and Society Requirement. Transfer courses will also be considered for this category.
4. AP/IB/Cambridge exam credit cannot be used to fulfill the Cultural/Global Requirement. Cultural and global understanding courses that are taken while studying abroad can be used to satisfy this requirement. In addition, transfer courses will also be considered for this category.
5. For the Nontechnical Electives requirement, students must complete a minimum of four courses totaling at least 36 units with a maximum of 18 units from AP/IB/Cambridge exam credit. In addition, transfer courses will also be considered for this category.

Double Counting Restrictions

Double counting occurs when a student attempts to use one course to meet more than one major, college, or university degree requirement. Any student attempting to double count a course should only do so in close consultation with all relevant academic advisor(s) and/or the Assistant Dean for Educational Initiatives to ensure that all degree requirements are appropriately met.

Generally speaking, students are permitted to double count courses from the MCS Core Education requirements towards their primary major, additional major, or additional minor requirements. However, the following information describes limitations to double counting policies within the MCS Core Education requirements themselves.

The goals of the MCS core technical breadth requirements are different from the goals of the non-technical breadth requirements. Therefore, students are not permitted to double count courses across the following categories/courses:

1. Technical Breadth Requirements (students must take 4 courses total, 1 each from the life sciences, physical sciences, and math, statistics and computer science).
2. Non-Technical Breadth Requirements (including the first-year seminar, first-year writing requirement, ENGAGE courses, third year seminar, cultural/global understanding requirement, and non-technical breadth requirements).

Furthermore, students are not permitted to double count courses across the following list of non-technical core requirements.

1. First-Year Writing Requirement
2. Global/Cultural Understanding Requirement
3. Science and Society Requirement
4. Non-Technical Breadth Requirements (36 units total)

Honors Degree Programs in MCS

Several of the departments in MCS offer students an opportunity to participate in a departmental honors degree program. Some of these programs result in a master's degree along with the bachelor's degree (see next section on accelerated master's programs). These programs are listed below; see the department's section of the catalog for more details.

- Honors Program in Research Biology
- Departmental Honors in Chemistry
- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences

Accelerated Master's Programs

Carnegie Mellon offers some accelerated master's programs for motivated students, whereby students complete both the bachelor's and the master's degree in four or five years. Some programs are in the student's home department in MCS as part of an honors program, while others are offered through one of our graduate schools at Carnegie Mellon. Below is a listing of the programs currently available to MCS students; please see the appropriate sections of the catalog for more details.

- Honors B.S./M.S. Program in Chemistry
- Honors B.S./M.S. Program in Mathematical Sciences
- Accelerated Master's Program in the Heinz College

Study Abroad

There are many programs for studying abroad, usually during your junior year. Please see the catalog section on Undergraduate Options for more details, and talk with the Office of International Education to get information and advice specifically for you.

Pre-Professional Programs

Many students in the Mellon College of Science decide to pursue professional training such as medical school or law school after completing their undergraduate work. Carnegie Mellon offers strong advising services to support these students. Through these programs, students get help with everything from course selection to identification of important experiential opportunities to the application process itself.

Health Professions Program

Faculty Contact: Jason D'Antonio

Please see the Undergraduate Options (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#healthproftext>) section for details on the Health Professions Program.

Pre-Law Advising Program

Faculty Contact: Joseph Devine

Please see the Undergraduate Options (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#prelawtext>) section for details on the Pre-Law Advising Program.

Intercollege Programs

Bachelor of Science and Arts Degree Program (BSA)

Students in the Bachelor of Science and Arts Degree Program (<http://coursecatalog.web.cmu.edu/servicesandoptions/intercollegeprograms/bxintercollege.html>) are jointly admitted to MCS and the College of Fine Arts (CFA). This is a degree program for students who are naturally gifted in both the arts and the sciences, and allows for the combining of talents in these areas.

Additional Major in Environmental and Sustainability Studies

The Dietrich College of Humanities & Social Sciences and the Mellon College of Science have joined together to establish the interdisciplinary Program in Environmental & Sustainability Studies offering a Minor or an Additional Major. Please see the Intercollege section (p.) of the catalog for requirements of these programs.

Applying Your Education Through Research

An important feature of education in MCS is the opportunity for undergraduate research experience. This experience may be arranged as a course taken for credit or occasionally as a part-time job. Our website (<https://www.cmu.edu/mcs/>) offers a range of useful information including links to faculty research areas, links to undergraduate research programs at other institutions, and ideas on how to get involved. Because of the strong research base of MCS, undergraduate research positions offer an exciting opportunity to apply your theoretical training to participate in the discovery of new knowledge.

Students can earn MCS Research Honors for significant research accomplishments; see the policy outlined below for the requirements.

Mellon College of Science Research Honors

Undergraduates in the Mellon College of Science will be awarded MCS College Honors at the completion of their degree if they have met one of these requirements:

1. Successfully completed the Honors BS/MS program in the Department of Chemistry or Department of Mathematical Sciences.
2. Successfully completed the departmental honors program in the Department of Biological Sciences or the Department of Chemistry.
3. Earned a cumulative grade point average of ≥ 3.20 (by the end of their seventh semester or by the time of graduation) and carried out significant research. Typically, this would consist of an academic project carried out for at least two semesters. However, a single project

that spans a summer and a semester or that the research mentor deems to be significant and sustained, even if the student worked for pay rather than credit, will be allowed. In addition, some form of public dissemination of this research, which has been approved by the MCS Associate Dean for Undergraduate Affairs, such as a peer reviewed publication, research thesis, or presentation at an external scientific meeting is required. The Meeting of the Minds by itself is not sufficient and participation in a pre-approved judged competition (eg. Sigma Xi, Math Department competition, or Psychology department competition) is necessary.

Final approval of nominations for MCS Honors will come from the Dean of MCS and the MCS Associate Dean for Undergraduate Affairs. Students can apply to their primary departmental advisor using this form on the MCS website: <https://www.cmu.edu/mcs/undergrad/advising/college-research-honors.html>.

Research Centers

The Mellon College of Science is home to a number of innovative research centers. These centers are particularly strong because of the interdisciplinary collaboration of their scientists. This interdisciplinary research brings international prestige to the college. Many students conduct undergraduate research with one of these centers.

The Bruce and Astrid McWilliams Center for Cosmology joins research efforts in astrophysics and particle physics and partners with computer science, statistics, and other disciplines to unravel the mysteries of the universe.

The Center of Atmospheric Particle Study's goal is to be the world leader in science, engineering, and policy covering the full role of fine particulate matter in the atmosphere. Our goal in research is to advance the state of knowledge across this spectrum substantially, to provide both policy-relevant research, and to participate directly and actively in the evolution of environmental policy related to particulate matter.

The Center for Computational Finance's mission is to improve the interaction between academic research and the finance industry.

The Center for Macromolecular Engineering's goals are to enhance the benefits of polymer science to society by developing new methods to prepare advanced polymer materials, train and develop tomorrow's scientists, and transfer technology to industry.

The Center of Nano-enabled Device and Energy Technologies' mission is to work on real-world problems that can be solved potentially with appropriate nano-enabled technologies.

The Center for the Neural Basis of Cognition is a joint program between Carnegie Mellon University and the University of Pittsburgh. It synthesizes the disciplines of basic and clinical neuroscience, cognitive psychology, and computer science, combining neurobiological, behavioral, computational, and brain imaging methods.

The Center for Nonlinear Analysis was established in 1991. A special focus for applications emphasizes new and innovative methods to study contemporary issues in materials science. The center has created a vigorous environment for collaboration among mathematical and allied scientists.

The Center for Nucleic Acids Science and Technology is a community of Carnegie Mellon scientists and engineers unified by interests in the chemistry, biology, and physics of DNA, RNA, and PNA (peptide nucleic acid).

The Institute for Green Science has been established as a research, education, and development center in which a holistic approach to sustainability science is being developed. The focus of the institute is in three areas: renewable energy technologies, chemical feedstocks, and benign alternatives to polluting technologies.

The Pittsburgh Supercomputing Center provides information on advanced scientific computing for engineering and research.

Academic Standards

MCS Dean's List

Each semester MCS recognizes those students with outstanding academic records by naming them to the Dean's List. The criteria for such recognition are as follows:

Dean's List

The student must earn a quality point average of at least 3.50 while completing a minimum of 36 factorable units and earning no incomplete grades.

Dean's List with High Honors

The student must earn a quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Academic Actions

In order to maintain good academic standing, students from the Mellon College of Science must attain at least minimum quality point averages for each semester (as well as cumulatively), and also make and maintain adequate progress toward completing their degree requirements. "Adequate progress towards graduation" generally means that students are successfully completing an average of 45 units per semester so that at the end of eight semesters they will have accumulated the minimum of 360 units required for graduation, have a cumulative QPA of at least 2.00, and completed all college General Education and primary major course requirements.

Specifically, MCS students will make satisfactory academic progress if they meet the following criteria:

- The semester GPA in the first year is ≥ 1.75 .
- The semester GPA beyond the first year is ≥ 2.00 .
- The cumulative QPA (excluding the first 2 semesters) is ≥ 2.00 .
- A student maintains full-time status (≥ 36 units) after the 10th day of classes in a semester.
- Completing $\geq 80\%$ of attempted units in a semester (calculated using total units carried when grades are entered). Grades of N, W, or R grade do not count as completed units.

When a student fails to meet minimum performance criteria, it normally results in an "academic action." Depending on the circumstances, one of the following actions is taken: academic warning, academic probation, continued probation, suspension, or drop. These academic actions are recommended by the college's departments based on the guidelines described below. However, the sequence of the academic actions is not automatic in all cases. Decisions may be based on unique individual student performance and circumstances, and are not determined purely on the basis of grades and quality point averages.

Academic actions are not meant to be punitive and are put into place to support student success. These actions are designed to notify students of specific academic requirements, outline goals for completion, and identify avenues of support to help students succeed. Students on academic action (except drop) will be asked to identify a plan of action to use resources to improve their academic performance. Resources can include the Student Academic Success Center, CaPS, UHS, and/or regular meetings with advisors, among others.

Warning

MCS students in their first year who earn a semester GPA between 1.75 and 1.99 will receive a warning of academic action. While this semester GPA is technically acceptable in the first 2 semesters on campus, it is indicative of academic difficulties and would trigger academic probation in subsequent semesters. Students on academic warning may not overload above 54 units in the semester of warning.

Probation

The action of probation will be taken if in any semester a student fails to make satisfactory academic progress as defined above.

The term of probation is one semester as a full-time student. Students on academic probation may not overload above 54 units in the semester of probation.

A student is occasionally continued on probation who has had one semester on probation and is not yet in good academic standing (as defined above) but whose record indicates that the standards are likely to be met at the end of the next semester of study. First-year students are no longer on probation at the end of the second semester if their semester QPA is 1.75 or above.

Suspension

A student who does not meet minimum standards at the end of one semester of probation will be suspended. The minimum period of suspension is one academic year (two semesters). At the end of that period a student may return to school on final academic probation by:

- Receiving permission in writing from the MCS Associate Dean for Undergraduate Affairs.
- Completing a Return from Leave form from Enrollment Services (<https://www.cmu.edu/hub/registrar/leaves-and-returns/>).

- Providing transcripts and clearance forms if the student has been in a degree program at another college or university, even though academic credit earned will not transfer to Carnegie Mellon unless prior approval has been granted by the MCS Associate Dean for Undergraduate Affairs.

Students on suspension can review a list of available resources on the HUB's website (<https://www.cmu.edu/hub/registrar/leaves-and-returns/access.html>). A student who has been academically suspended and who is not employed by the University must absent themselves from campus and is, for the term of the suspension, barred from all activities and affiliations that stem from one's status as an enrolled student. These include registering or enrolling for courses, sitting in on classes, living in residence halls or Greek houses, membership and participation in student activities, and employment in student jobs. (NOTE: Exceptions to the restriction from student jobs for students on academic suspension will in general be granted for summer employment if the position was accepted prior to the decision to suspend.)

Notably, employment within the university in non-student jobs is possible for students on academic suspension, subject to the hiring criteria of the hiring department. However, a student on academic suspension wishing to accept a job on campus must speak with the Associate Dean of the student's college to ensure that the employment will not constitute a violation of the terms of suspension. The Associate Dean will generally allow such employment, in consultation with the Dean of Student Affairs. One employment benefit not available to students on academic suspension who accept a full-time job with the University is the option to take courses through tuition remission. The option to take courses becomes available only after the academic suspension is over.

Students returning from suspension should plan to work with their advisor and Associate Dean for undergraduate affairs at least 30 days prior to the semester they plan to return. Ideally, students will connect with the Associate Dean several weeks before registration for the semester of planned return. In addition to the steps for a smooth return (<https://www.cmu.edu/hub/registrar/leaves-and-returns/>) described on the Registrar's website, MCS students should prepare a short (1000 word maximum) essay describing how they've been preparing for a successful return to CMU.

Upon return, students will be on final academic probation. Students in this situation must work closely with all available resources (particularly their academic advisor) to ensure all resources are being properly used to maximize success to avoid progression to academic drop. Students returning on final academic probation may not overload above 54 units in the semester of return.

Drop

This is a permanent severance from the Mellon College of Science. Students are dropped when it seems clear that they will not be able to meet minimum standards. A student who has been suspended and who fails to meet minimum standards after returning to school is dropped.

A student who has been academically dropped and who is not employed by the University must absent themselves from campus and is barred from all activities and affiliations that stem from one's status as an enrolled student. These include registering or enrolling for courses, sitting in on classes, living in residence halls or Greek houses, membership and participation in student activities, and employment in student jobs. (NOTE: Exceptions to the restriction from student jobs for students on academic drop will in general be granted for summer employment if the position was accepted prior to the decision to drop.)

Appeals of Academic Actions

In accordance with the Appeal of Academic Actions Policy (<https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html>) outlined in The Word student handbook:

"If a student believes an academic action is inconsistent with the policies of the college, a student should:

1. Submit a formal written appeal to the Associate Dean of the college responsible for the decision, with a copy to the dean, requesting review of the action including all relevant materials to substantiate the inconsistency in policy and to support their concerns.
2. The Dean of the college, or the dean's designate, will review the appeal and issue a decision and the basis for it within 30 days.

If, after carrying out the steps of either process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all documents and a formal letter of appeal to the provost. The Provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days, or as soon thereafter as practical."

Course Overloads

Overloading is defined as taking more than the equivalent of five full-semester courses in one semester; for MCS students overload means registering for more than 54 units in one semester. Eligibility to overload is defined as:

1. Student must be in good academic standing (not on any academic action listed above).
2. Student must have a QPA of at least 3.25 in the last completed semester or student must have a current cumulative QPA of at least 3.25.
3. Students new to the college and university (i.e., first-year students and new external transfer students from outside of CMU) may not overload during their first Carnegie Mellon semester.
4. Advisors can, in accordance with these policies, approve overloads up to 61 units. Associate Dean approval is required for overload requests over 61 units. In addition to the other criteria listed above, students must have also successfully completed ≥ 45 units in a previous semester to request to overload > 61 units.

Eligibility to overload based on QPA does not automatically allow the student to register for an overload. Rather, students must petition and discuss the proposed overload with their primary academic advisor. The discussion will include the reason for overload (additional major/minor, trying to graduate early, etc.). If approved, the academic advisor will increase the student's unit maximum for the relevant semester.

The first opportunity to register for a course overload is after registration week for the proposed overload semester. Registration week for the spring semester is usually the third week in November; for the fall semester, it is usually the third week in April. Consult the official university academic calendar for the exact dates.

If as a result of final grades for the current semester a student approved to overload for the next semester falls below the overload eligibility criteria listed above, the academic advisor may withdraw the overload permission. Students thus affected are responsible for resolving this in consultation with their academic advisor.

Students may appeal their advisor's overload request decision to the Associate Dean for Undergraduate Affairs in writing (email is appropriate for this petition, but a meeting may be requested by the Associate Dean to discuss the appeal).

Transfer into MCS Departments

This section describes the variety of entry points into the Mellon College of Science for students already admitted to a university (Carnegie Mellon or another university). All prospective students should contact the Office of Admission for details about the application process for Carnegie Mellon University.

Students entering MCS or already declared in MCS:

Entering undergraduate students admitted to MCS can choose to pursue any major within MCS. This choice must be made prior to the first semester of the sophomore year (normally during the second semester of the first year) and does not require approval by any department.

Students who have declared a major in MCS and wish to transfer into another department within MCS must have approval (<https://www.cmu.edu/mcs/undergrad/advising/forms/>) from the new department (generally through the primary academic advisor (<https://www.cmu.edu/mcs/undergrad/advising/>) in the new department) and from the MCS Associate Dean for Undergraduate Affairs. Students wishing to transfer into the Mathematical Sciences Department must have completed 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs AND 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory with grades of B or better in both courses as well as an overall QPA of 3.5 or higher.

MCS undergraduate students beyond the first year wishing to transfer into another MCS department may do so if they are not on academic probation and if there is room in the department of their choice. If the demand for any department exceeds the space available, then the department will admit students based on a comparative evaluation of all applicants at the end of each semester, up to the limit of available space.

Students enrolled in another college at Carnegie Mellon:

Undergraduate students admitted to colleges other than MCS and wishing to transfer into an MCS department during their first year should consult with the MCS Associate Dean for Undergraduate Affairs (<https://www.cmu.edu/mcs/undergrad/advising/>). Students may submit an internal transfer request (<https://www.cmu.edu/mcs/undergrad/advising/forms/>) no earlier than the first day of their second semester.

Potential transfer students into the departments of Biological Sciences, Chemistry, or Physics must also have credit for 21-120 Differential and Integral Calculus and, depending on major choice, should have completed one of the following courses at Carnegie Mellon: 03-121 Modern Biology, 09-105 Introduction to Modern Chemistry I, or 33-12133-121 Physics I for Science Students. Higher level courses will also be considered by the MCS Associate Dean as alternatives to these courses. Students wishing to transfer into the Mathematical Sciences Department must have completed 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs AND 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory with grades of B or better in both courses as well as an overall QPA of 3.5 or higher.

Undergraduate students not in MCS and wishing to transfer into a department in MCS beyond the first semester will be considered for transfer on a space available/academic performance basis. An MCS department may refuse a transfer to a non-MCS student if there are space restrictions and/or if the student's chance for success is determined to be questionable based on past academic performance.

Students wishing to transfer from another university into an MCS department:

A student first applies through the Office of Admission. If the Office of Admission believes the applicant is acceptable, the student's record is sent to the appropriate department for evaluation and a decision on acceptance. The MCS department head has the right to refuse to accept the student if there are space restrictions and/or if the student's chance for success in the MCS department is determined to be questionable based on past academic performance.

Graduation Requirements

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.00 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.00, this requirement is modified to be a cumulative QPA of at least 2.00 for all courses taken after the freshman year. Note, however, the cumulative QPA that appears on the student's final transcript will be calculated based on all grades in all courses taken, including freshman year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

A minimum of 360 units must be completed. This will include the MCS Core Courses (technical and nontechnical electives) and all departmental course requirements.

Students will be required to meet the residency requirement and to have met all financial obligations to the university before being awarded a degree. The residency requirement is detailed in the Academic Regulations section of the catalog. A student may seek permission to modify graduation requirements by petition to the MCS College Council.

Graduation Honors

There are two types of honors awarded at graduation.

University Honors

University Honors are automatically awarded to students who have earned a cumulative Q.P.A. of 3.5 or better after either seven semesters or by the time they are certified for graduation.

College Research Honors

Please see the section "Mellon College of Science Research Honors (p. 586)" for information on how to qualify for College Research Honors.

Faculty

MAGGIE BRAUN, Associate Dean for Undergraduate Affairs – Ph.D. ,

JASON D'ANTONIO, Director of Health Professions Program – Ph.D.,

KENNETH HOVIS, Assistant Dean for Educational Initiatives – Ph.D.,

MANFRED PAULINI, Associate Dean for Graduate and Faculty Affairs – Ph.D.,

MICHAEL YOUNG, Associate Dean for Diversity – Ph.D.,

Administration

KRYSTALYN KOVACS, Undergraduate Programs Coordinator, HPP

ABIGAIL PINNOW, Undergraduate Programs Administrator, MCS

TARA PRIMIERO, Senior Academic Advisor, MCS

Department of Biological Sciences

Veronica Hinman, Department Head

Amanda Willard, Director of Undergraduate Studies

Location: Doherty Hall 1321
www.cmu.edu/bio (<http://www.cmu.edu/bio/>)

A major revolution is occurring in the field of biological sciences. Biology is undergoing unprecedented technological advances in biochemistry, biophysics, cell biology, genetics, molecular biology, developmental biology, neuroscience and computational biology. Carnegie Mellon's Department of Biological Sciences is nationally recognized as one of the outstanding departments in these areas. Advances in basic research are already being used to solve problems, not only in medicine and public health, but also in areas such as agriculture, forestry, mining, energy, and in industrial and pharmaceutical manufacturing processes. The department provides its students with an education that has both intellectual breadth and depth of exposure to modern research biology. This education can be used to gain employment immediately after graduation in government, industry or academic research laboratories, or to pursue graduate studies in a variety of areas such as science, medicine, public health, law, or business. A degree in biological sciences provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (p. 20) section in this catalog or www.cmu.edu/hpp (<http://www.cmu.edu/hpp/>) for more information.)

The department offers a Bachelor of Science (B.S.) degree in Biological Sciences. This program has a distinctive core curriculum that provides a foundation in biology, chemistry, computer science, mathematics, and physics. In addition to the core courses, the program includes six biology electives, free electives as well as humanities, social science and fine arts electives. With these electives, students can shape a degree program according to their own interests and career goals. For students who have an interest in a particular field of biology and wish to have a specialized focus, the department offers options in biochemistry, biophysics, cell biology, computational biology, developmental biology, genetics, molecular biology and neuroscience that provide the relevant training in each area. The options are especially recommended for students who are considering graduate school in one of these areas.

In this exciting era that includes the influence of biology and the life sciences on many fields from medicine to law, the in-depth exposure to multiple disciplines provides opportunities for students to prepare for involvement at the forefront of emerging new fields, markets, and policy changes. The Department of Biological Sciences at Carnegie Mellon is working at these new interfaces through interdisciplinary research and educational programs. Innovative interdisciplinary degrees which are offered by the department include the inter-college B.S. degree in Neuroscience as well as the unified B.S. degree in Biological Sciences and Psychology. Students also pursue interests at the interface between the arts and sciences through the Bachelor of Science and Arts (B.S.A.) degree program combining biological sciences or neurobiology with a discipline in the College of Fine Arts. A stand-alone Bachelor of Arts (B.A.) degree is available for students who wish to expand their educational training into other fields. Many students choose to broaden their education by pursuing minors and additional majors in disciplines throughout the university, not just within the Mellon College of Science.

One of the most important features of the Department of Biological Sciences is the opportunity for undergraduate students to interact with faculty. Providing a solid foundation to scientific practice is critical; therefore, the department offers first-year students a variety of inquiry-based, hands-on courses that incorporate a wide range of topics and interests within Biological Sciences. These courses kick-start the transformation of science students to scientists. We encourage our students to get to know their faculty through one of these courses, or through mentored, independent research projects in the faculty laboratories. Our faculty members are prominent research scientists who also teach beginning and advanced courses. The upper level teaching laboratories are located in the same building as the faculty research laboratories and share scientific equipment. We encourage students to make themselves aware of the research areas of the faculty and to develop research projects with faculty. While such research is usually most important in the senior year, it may begin earlier in a student's undergraduate training. The department has an Honors Program in Research Biology to facilitate a more intensive involvement in research for eligible students. During the past four years, more than 85 percent of the undergraduate biology majors have worked with faculty on their

research and, in some cases, have been co-authors of research papers and have given presentations at national meetings.

Since the fall of 2011, the Department of Biological Sciences has offered a B.S. degree in Biological Sciences at Carnegie Mellon University in Doha, Qatar. Students enrolled in this degree program will also complete the requirements outlined below. One of the required courses for the CMU-Qatar program is offered through a collaboration with the Weill Cornell Medical College in Qatar. For a listing of how the degree requirements are fulfilled for students enrolled in Doha, please consult the CMU-Qatar website (www.qatar.cmu.edu/curriculum-bs) (<https://www.qatar.cmu.edu/curriculum-bs/>)).

Program Outcomes

Upon graduation recipients of the B.S. or B.A. degree in Biological Sciences will:

- Use the basic concepts and experimental, computational, and theoretical methods of the core fields of science, mathematics and technology.
- Use foundational knowledge from the natural sciences and mathematics for advanced work in the discipline.
- Understand and apply the scientific method.
- Apply disciplinary knowledge toward solving problems.
- Use modern methods for finding and sharing current scientific information and primary literature.
- Convey information including scientific content in written and oral formats within Biological Sciences.
- Work in multidisciplinary and culturally diverse teams.
- Demonstrate proper values and ethics within Biological Sciences, the University, and the larger scientific community.

B.S. Biological Sciences

The Bachelor of Science (B.S.) in Biological Sciences is built around a core program and elective units as detailed in the following section.

Degree Requirements:

| Biological Sciences | | Units |
|----------------------------|--|------------|
| 03-151 | Honors Modern Biology | 10 |
| | or 03-121 Modern Biology | |
| 03-201 | Undergraduate Colloquium for Sophomores | 2 |
| 03-220 | Genetics | 9 |
| | or 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 | Honors Biochemistry | 9 |
| | or 03-232 Biochemistry I | |
| 02-250 | Introduction to Computational Biology | 12 |
| 03-320 | Cell Biology | 9 |
| 03-343 | Experimental Techniques in Molecular Biology | 12 |
| 03-344 | Experimental Biochemistry | 12 |
| | or 03-345 Experimental Cell and Developmental Biology | |
| | or 03-346 Experimental Neuroscience | |
| 03-411 | Topics in Research | 1 |
| 03-412 | Topics in Research | 1 |
| 03-xxx | Biological Sciences Electives ¹ | 54 |
| Total Biology units | | 131 |

¹ Details on electives can be found in the "Biological Sciences Electives" section (see below).

| Mathematics, Physics and Computer Science | | Units |
|---|--|-------|
| 15-110 | Principles of Computing | 10 |
| | or 15-112 Fundamentals of Programming and Computer Science | |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-124 | Calculus II for Biologists and Chemists | 10 |
| | or 21-122 Integration and Approximation | |
| 33-121 | Physics I for Science Students | 12 |

| | | |
|----------------------------|---|-----------|
| or 33-141 | Physics I for Engineering Students | |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| or 33-142 | Physics II for Engineering and Physics Students | |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| Total Science units | | 54 |

| | | |
|------------------------------|---|-----------|
| Chemistry | | Units |
| 09-105 | Introduction to Modern Chemistry I ² | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |
| Total Chemistry units | | 56 |

² Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

| | | |
|--|--|------------|
| Elective Units | | Units |
| Free Electives | | 48 |
| MCS Nontechnical Breadth Requirements ³ | | 72 |
| Total Elective units | | 120 |

³ For more information on the MCS Technical and Nontechnical Breadth Requirements, please refer to the MCS General Education Requirements (p. 583) section of this catalog. MCS Technical Breadth Requirements are all met through the required curriculum for the Biological Sciences degree (see below).

Minimum number of units required for degree: 360

MCS Technical Breadth Requirements

Majors entering CMU and majoring in Biological Sciences (or affiliated majors) in the Fall of 2015 or beyond will fulfill the MCS Technical Breadth requirements as follows:

1. Life Sciences: any courses in this category except for the 03-xxx courses. For the B.S. in Biological Sciences, this will be fulfilled by 02-250.
2. Physical Sciences: 09-105, 09-106, 33-121 and 33-122
3. Math/CS/Stats: 21-120 and (21-122 or 21-124)
4. STEM Elective: will be filled by courses above or any STEM course from the approved list.

Biological Sciences Electives

The following specifications apply to Biological Sciences electives:

- At least 18 units must be at the 03-3xx level or above, exclusive of 03-445 and 03-545 and interdisciplinary electives.
- Up to three interdisciplinary electives may count as general biology electives.
- Up to 18 units of 03-445 Undergraduate Research and/or 03-545 Honors Research may count as general biology electives; a maximum of 36 units can count for the minimum units required for graduation.
- Courses in biology taken through cross-registration or study abroad at another university may count as electives if prior permission is obtained from the Carnegie Mellon Department of Biological Sciences advisor.

Departmental Electives Group

| | | |
|--------|---|------|
| 03-117 | Frontiers, Analysis, and Discovery in Biological Sciences | 6 |
| 03-118 | Beer: A Yeast's Perspective | 6 |
| 03-119 | Biology for Life Special Topics Micro | 3 |
| 03-120 | Biology for Life Special Topics Mini | Var. |
| 03-124 | Modern Biology Laboratory | 9 |
| 03-125 | Evolution | 9 |
| 03-128 | Biology for Life Special Topics | 9 |
| 03-129 | Human Health and Disease ^{*Offered only in Doha} | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 03-135 | Structure and Function of the Human Body | 9 |
| 03-140 | Ecology and Environmental Science | 9 |

| | | |
|---------------|--|------|
| 03-161 | Molecules to Mind | 9 |
| 03-230 | Intro to Mammalian Physiology ^{*Offered only in Doha} | 9 |
| 03-327 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 9 |
| 03-350 | Developmental Biology | 9 |
| 03-351 | Computation and Biology Integrated Research Lab | 9 |
| 03-360/02-319 | Genomics and Epigenetics of the Brain | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 03-380 | Virology ^{*Offered only in Doha} | 9 |
| 03-390 | Molecular and Cellular Immunology | 9 |
| 03-391 | Microbiology | 9 |
| 03-410 | Special Topics in Biological Sciences | Var. |
| 03-435 | Cancer Biology | 9 |
| 03-439 | Introduction to Biophysics | 10 |
| 03-442 | Molecular Biology | 9 |
| 03-445 | Undergraduate Research | Var. |
| 03-451 | Advanced Developmental Biology and Human Health | 9 |
| 03-511 | Computational Molecular Biology and Genomics | 9 |
| 03-545 | Honors Research | 9 |
| 03-711 | Computational Molecular Biology and Genomics | 12 |
| 03-713 | Bioinformatics Data Integration Practicum | 6 |
| 03-727 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 12 |
| 03-728 | Genome Editing Biotechnology | 6 |
| 03-729 | Entrepreneurship and protein-based drug development | 6 |
| 03-730 | Advanced Genetics | 12 |
| 03-741 | Advanced Cell Biology | 12 |
| 03-742 | Advanced Molecular Biology | 12 |
| 03-751 | Advanced Developmental Biology and Human Health | 12 |
| 03-762 | Advanced Cellular Neuroscience | 12 |
| 03-763 | Advanced Systems Neuroscience | 12 |
| 03-791 | Advanced Microbiology | 12 |
| 03-871 | Structural Biophysics | 12 |

Interdisciplinary Electives Group

Up to three of the following courses may count as general biology electives:

| | | |
|--------|--|----|
| 02-331 | Modeling Evolution | 12 |
| 02-425 | Computational Methods for Proteogenomics and Metabolomics | 9 |
| 02-450 | Automation of Scientific Research | 9 |
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| 02-518 | Computational Medicine | 12 |
| 02-740 | Bioimage Informatics | 12 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | 9 |
| 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | 9 |
| 09-803 | Chemistry of Gene Expression | 12 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-260 | Differential Equations | 9 |
| 36-200 | Reasoning with Data | 9 |
| 42-202 | Physiology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

Options for the B.S. in Biological Sciences

Students who wish to specialize in a particular area of biology can do so through a set of departmentally defined options. Options are not required

and need not be declared. The elective courses required for each of the options are listed below. Students can elect to complete a maximum of two options. Please discuss interest in these options with the Carnegie Mellon Department of Biological Sciences advisor to plan out any pre-requisite coursework and identify appropriate course alternatives in the event that a graduate-level course is not being offered during a particular academic year.

Biochemistry Option

Required Biology Electives:

| | | |
|-----------|------------------------------|------|
| 21-259 | Calculus in Three Dimensions | 9-10 |
| or 21-260 | Differential Equations | |

Any ONE of the following courses:

| | | |
|--------|--|---|
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | 9 |
| 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | 9 |
| 09-521 | Metals in Biology: Function and Reactivity | 6 |

Recommended Biology Electives:

| | | |
|--------|----------------------------|----|
| 03-442 | Molecular Biology | 9 |
| 03-439 | Introduction to Biophysics | 10 |
| 03-871 | Structural Biophysics | 12 |

Biophysics Option

Required Biology Electives:

| | | |
|-----------|------------------------------|------|
| 03-439 | Introduction to Biophysics | 10 |
| 21-259 | Calculus in Three Dimensions | 9-10 |
| or 21-260 | Differential Equations | |

Recommended Biology Electives:

| | | |
|--------|-----------------------|----|
| 03-871 | Structural Biophysics | 12 |
|--------|-----------------------|----|

Cell Biology Option

Required Biology Electives:

| | | |
|--------|-----------------------|----|
| 03-350 | Developmental Biology | 9 |
| 03-741 | Advanced Cell Biology | 12 |

Any ONE of the following courses:

| | | |
|--------|-----------------------------------|---|
| 03-362 | Cellular Neuroscience | 9 |
| 03-390 | Molecular and Cellular Immunology | 9 |

Computational Biology Option

Required Biology Electives:

| | | |
|--------|--|----|
| 03-711 | Computational Molecular Biology and Genomics | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |

Any ONE of the following courses:

| | | |
|--------|-------------------------------------|----|
| 36-200 | Reasoning with Data | 9 |
| 21-260 | Differential Equations | 9 |
| 21-241 | Matrices and Linear Transformations | 11 |

Recommended Biology Electives:

| | | |
|--------|--|----|
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| 15-451 | Algorithm Design and Analysis | 12 |

Developmental Biology Option

Required Biology Electives:

| | | |
|--------|---|----|
| 03-350 | Developmental Biology | 9 |
| 03-442 | Molecular Biology | 9 |
| 03-751 | Advanced Developmental Biology and Human Health | 12 |

Recommended Biology Electives:

| | | |
|--------|-----------------------|----|
| 03-741 | Advanced Cell Biology | 12 |
|--------|-----------------------|----|

Genetics Option

Required Biology Electives:

| | | |
|--------|--|----|
| 03-327 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 9 |
| 03-442 | Molecular Biology | 9 |
| 03-730 | Advanced Genetics ⁶ | 12 |

⁶ Minimum grade of B in or 03-220 required.

Recommended Biology Electives:

| | | |
|--------|--------------|---|
| 03-391 | Microbiology | 9 |
|--------|--------------|---|

Molecular Biology Option

Required Biology Electives:

| | | |
|--------|--|----|
| 03-442 | Molecular Biology | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | 9 |
| 03-727 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 12 |

Recommended Biology Electives:

| | | |
|--------|-----------------------------------|----|
| 03-390 | Molecular and Cellular Immunology | 9 |
| 03-391 | Microbiology | 9 |
| 03-730 | Advanced Genetics | 12 |

Neuroscience Option

Required Biology Electives:

| | | |
|--------|------------------------------------|---|
| 03-362 | Cellular Neuroscience ⁷ | 9 |
| 03-363 | Systems Neuroscience ⁷ | 9 |

Any ONE of the following courses:

| | | |
|--------|--|---|
| 03-133 | Neurobiology of Disease | 9 |
| 03-350 | Developmental Biology | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 42-202 | Physiology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

⁷ One of these courses must be completed at the Graduate Level (Complete either 03-762 or 03-763).

B.S. Biological Sciences/Neuroscience Track

The Bachelor of Science in Biological Sciences/Neuroscience Track provides an option for those Biological Sciences majors who are interested in an intensive curricular focus in neuroscience. The requirements of the Track are the same as those listed for the B.S. in Biological Sciences with the following changes to the biological sciences elective requirements:

Degree Requirements:

| | | |
|--------|-----------------------|---|
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |

Plus three of the following electives:

| | | |
|---------------|--|---|
| 03-133 | Neurobiology of Disease | 9 |
| 03-350 | Developmental Biology | 9 |
| 03-360/02-319 | Genomics and Epigenetics of the Brain | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 15-385 | Introduction to Computer Vision | 6 |
| 15-386 | Neural Computation | 9 |
| 42-202 | Physiology | 9 |
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

B.S. Neuroscience

The Bachelor of Science in Neuroscience is listed in the Intercollege Programs (p. 890) section of this catalog. It is a joint degree program offered between the Mellon College of Science and the Dietrich College of Humanities and Social Sciences. Current MCS students interested in

pursuing this degree should contact Biological Sciences Undergraduate Programs Office (bio-ungrad@andrew.cmu.edu).

B.S. Biological Sciences and Psychology

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 321) and MCS (p. 582) are found on their respective Catalog pages.

Degree Requirements:

| Biological Sciences | | Units |
|----------------------------|--|-----------|
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 03-220 | Genetics | 9 |
| or 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 | Honors Biochemistry | 9 |
| 03-320 | Cell Biology | 9 |
| 03-343 | Experimental Techniques in Molecular Biology | 12 |
| 03-411 | Topics in Research | 1 |
| 03-412 | Topics in Research | 1 |
| 03-xxx | General Biology Elective ¹ | 9 |
| 03-3xx | Advanced Biology Elective ¹ | 18 |
| Total Biology units | | 78 |

¹ Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

| Mathematics, Statistics, Physics and Computer Science | | Units |
|---|--|--------------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-124 | Calculus II for Biologists and Chemists | 10 |
| or 21-122 | Integration and Approximation | |
| 36-200 | Reasoning with Data | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |
| 33-121 | Physics I for Science Students ² | 12 |
| or 33-141 | Physics I for Engineering Students | |
| 15-110 | Principles of Computing | 10-12 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| Total Science units | | 63-65 |

² MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

| Chemistry | | Units |
|------------------------------|---|-----------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |
| Total Chemistry units | | 56 |

| Psychology Courses | | Units |
|--------------------|--|-------|
| 85-102 | Introduction to Psychology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-2xx | Survey Psychology Courses [*] | 18 |

| | | |
|-----------|--|----|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| or 85-314 | Cognitive Neuroscience Research Methods | |
| or 85-320 | Research Methods in Developmental Psychology | |
| or 85-330 | Analytic Research Methods | |
| or 85-340 | Research Methods in Social Psychology | |
| 85-3xx | Advanced Psychology Electives | 18 |

Total Psychology units 63

* Excluding 85-261 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)

| | | |
|--------|------------------------------|---|
| 85-3xx | Advanced Psychology Elective | 9 |
| or | | |
| 03-3xx | Advanced Biology Elective | 9 |

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)

| | | |
|--------|--|----|
| 03-344 | Experimental Biochemistry | 12 |
| 03-345 | Experimental Cell and Developmental Biology | 12 |
| 03-346 | Experimental Neuroscience | 12 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

| Elective Units | | Units |
|---|--|-------|
| Free Electives | | 33-36 |
| MCS Nontechnical Breadth or DC General Education requirements | | 36-48 |

Total Elective units 69-84

Minimum number of units required for degree: 360

B.A. Biological Sciences

The Department of Biological Sciences offers a Bachelor of Arts (B.A.) degree that is intended for students who wish to combine their interest in science with their interest(s) in other discipline(s) across campus. The requirements for the B.A. degree are distributed as follows:

Degree Requirements:

| Biological Sciences | | Units |
|----------------------------|--|--------------|
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 03-201 | Undergraduate Colloquium for Sophomores | 2 |
| 03-220 | Genetics | 9 |
| or 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 | Honors Biochemistry | 9 |
| or 03-232 | Biochemistry I | |
| 03-320 | Cell Biology | 9 |
| 03-343 | Experimental Techniques in Molecular Biology | 9-12 |
| or 03-124 | Modern Biology Laboratory | |
| 03-411 | Topics in Research | 1 |
| 03-412 | Topics in Research | 1 |
| 03-xxx | General Biology Electives ¹ | 18 |
| 03-3xx | Advanced Biology Electives ¹ | 18 |
| Total Biology units | | 86-89 |

¹ Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

| Chemistry | | Units |
|-----------|---|-------|
| 09-105 | Introduction to Modern Chemistry I ² | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |

| | | |
|--------|-------------------------------------|---|
| 09-218 | Organic Chemistry II | 9 |
| 09-207 | Techniques in Quantitative Analysis | 9 |

Total Chemistry units 47

² Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

| | |
|--|-------|
| Mathematics, Physics, and Computer Science | Units |
| 15-110 Principles of Computing | 10 |
| or 15-112 Fundamentals of Programming and Computer Science | |
| 21-120 Differential and Integral Calculus | 10 |
| 21-124 Calculus II for Biologists and Chemists | 10 |
| or 21-122 Integration and Approximation | |
| 33-121 Physics I for Science Students | 12 |
| or 33-141 Physics I for Engineering Students | |
| 33-122 Physics II for Biological Sciences & Chemistry Students | 9 |
| or 33-142 Physics II for Engineering and Physics Students | |
| 99-101 Computing @ Carnegie Mellon | 3 |

Total Science units 54

| | |
|---------------------------------------|-------|
| Elective courses | Units |
| MCS Nontechnical Breadth Requirements | 72 |
| Free Electives | 96-99 |

Total Elective units 168-171

360 Minimum number of units required for degree:

Additional Major and Dual Degree in Biological Sciences

Biological Sciences may be taken as an additional major (also known as a "double major") or as a second degree, with another department granting the primary degree. The rules of the Biological Sciences Department for these two options are distinct, as discussed below.

Additional Major

In order to receive an Additional Major in Biological Sciences, with another department granting the primary degree, all requirements listed below must be fulfilled:

| | |
|--|-------|
| Biological Sciences | Units |
| 03-151 Honors Modern Biology | 10 |
| or 03-121 Modern Biology | |
| 03-201 Undergraduate Colloquium for Sophomores | 2 |
| 03-220 Genetics | 9 |
| or 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 Honors Biochemistry | 9 |
| or 03-232 Biochemistry I | |
| 02-250 Introduction to Computational Biology ¹ | 12 |
| 03-320 Cell Biology | 9 |
| 03-343 Experimental Techniques in Molecular Biology | 12 |
| 03-344 Experimental Biochemistry | 12 |
| or 03-345 Experimental Cell and Developmental Biology | |
| or 03-346 Experimental Neuroscience | |
| 03-411 Topics in Research | 1 |
| 03-412 Topics in Research | 1 |
| 03-xxx Biological Sciences Electives ² | 54 |

Total Biology units 131

¹This course requires 15-110 or 15-112 as a prerequisite.

²Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

| | |
|---|-------|
| Chemistry | Units |
| 09-105 Introduction to Modern Chemistry I ³ | 10 |
| or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 Modern Chemistry II | 10 |
| 09-217 Organic Chemistry I | 9 |
| 09-218 Organic Chemistry II | 9 |

| | | |
|--------|---|---|
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |

Total Chemistry units 56

³ Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Minimum number of units required for additional major:
187

Dual Degree

In order to receive a Dual Degree in another subject and Biological Sciences, all requirements of the Biological Sciences degree must be fulfilled. Students may choose to complete the B.A. or the B.S. in Biological Sciences, with or without Options. Students must complete all technical and non-technical requirements, and should consult with the Carnegie Mellon Biological Sciences advisor for questions about double counting. The number of units required for a Dual Degree is 90 more than the total units required by the department requiring the fewer total units. Since Biological Sciences requires 360 units, the lowest possible minimum for a Dual Degree with Biological Sciences is 450 units.

Minor in Biological Sciences

All university students are eligible to pursue a minor in biological sciences in conjunction with a major in any other department in the university. A minimum of six biological sciences courses (and two chemistry prerequisites) must be completed to fulfill the minor in biological sciences. The curriculum includes four required courses and two elective courses as specified below. Units awarded for undergraduate research are not applicable to elective courses. Courses taken in other departments or colleges will be considered on an individual basis.

Courses for the Minor in Biological Sciences

| | |
|---|-------|
| Prerequisites: | Units |
| 09-105 Introduction to Modern Chemistry I | 10 |
| 09-217 Organic Chemistry I | 9 |

| | |
|--|-------|
| Required courses: | Units |
| 03-121 Modern Biology | 9 |
| or 03-151 Honors Modern Biology | |
| 03-220 Genetics | 9 |
| or 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |
| 03-231 Honors Biochemistry | 9 |
| or 03-232 Biochemistry I | |
| 03-320 Cell Biology | 9 |
| 03-xxx General Biology Elective ¹ | 9 |
| 03-3xx Advanced Biology Elective ¹ | 9 |

¹Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

Minimum number of units required for the Minor in Biological Sciences: 73

Minor in Neuroscience

The curriculum within the Neuroscience minor will allow students from various disciplines to gain fundamental knowledge of neuroscience concepts. The interdisciplinary nature of the coursework echoes the nature of the field itself; students will select courses from the natural, social, and computer sciences. Neuroscientists not only require foundational knowledge of molecular, cellular, and systems neuroscience, but they should also understand the behavioral significance and appreciate how computational work and imaging techniques can aid in clarifying normal and abnormal functioning of these fundamental processes.

Students pursuing the minor in Neuroscience will:

- Acquire foundational knowledge of the basic biological foundations of the nervous system, from the cellular through systems levels.
- Understand the effects of basic neurological function on behavior, including cognition.
- Gain an appreciation of the interdisciplinary nature of the field of neuroscience.

NOTE: Because the curriculum within this minor may overlap with some degree requirements, no more than 2 courses fulfilling Neuroscience Minor

requirements may count towards the requirements of a student's major or other minor.

Course Requirements

Minimum units required for Neuroscience minor 63

Required courses (4):

| | Units |
|--|-------|
| 03-121 Modern Biology | 9 |
| or 03-151 Honors Modern Biology | |
| 03-362 Cellular Neuroscience | 9 |
| 03-363 Systems Neuroscience | 9 |
| 85-219 Foundations of Brain and Behavior | 9 |
| or 03-161 Molecules to Mind | |

Distribution Requirements:

Three courses, including at least 1 from each of the following categories:

| Approaches to Neuroscience Category | Units |
|--|-------|
| 15-386 Neural Computation | 9 |
| 15-883 Computational Models of Neural Systems | 12 |
| 85-412 Cognitive Modeling | 9 |
| 85-414 Cognitive Neuropsychology | 9 |
| 85-429 Cognitive Brain Imaging | 9 |
| 85-435 Biologically Intelligent Exploration | 9 |
| Cognitive Neuroscience Category | Units |
| 03-133 Neurobiology of Disease | 9 |
| 03-365 Neural Correlates of Learning and Memory | 9 |
| 03-366 Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 85-211 Cognitive Psychology * | 9 |
| 85-370 Perception | 9 |
| 85-406 Autism: Psychological and Neuroscience Perspectives | 9 |

*NOTE: 85-213 may be used instead of 85-211 when offered

Masters Degrees

Students who are interested in more advanced training in the intersection of biology and computation or biology and engineering may want to consider the Department of Biological Science's Masters programs: the Master of Science in Quantitative Biology and Bioinformatics (https://www.cmu.edu/bio/graduate/ms_quant_bioinformatics/), the Master of Science in Computational Biology (<https://www.cmu.edu/ms-compbio/>) (joint with the Department of Computational Biology), or the Master of Science in Biotechnology and Pharmaceutical Engineering (<https://www.cmu.edu/ms-biotech-pharma/>) (joint with the Department of Chemical Engineering). For more information about these programs, contact the Biological Sciences Graduate Programs Office (bio-graduate-office@andrew.cmu.edu).

Honors Program in Research Biology

The departmental Honors Program offers an opportunity to become extensively involved in research. The program requires students to conduct an independent project and to prepare a formal thesis that is written and defended in the senior year. This program does not preclude a student from completing any of the options within the department nor is it the only way in which students can participate in undergraduate research, although it is excellent preparation for graduate studies. Please contact the Carnegie Mellon Biological Sciences advisor for more information.

Transfer credit for Modern Biology

Students wishing to transfer credit for 03-121 Modern Biology from another institution must meet the following requirements:

1. The course in question should have at least an 80% match in topics with 03-121. Topics in 03-121 cover the genetic, molecular, cellular, developmental, and evolutionary mechanisms that underlie biological processes and include: Cell theory; Cell chemistry; Cell structure; Function and structure of proteins, DNA, RNA, lipids and carbohydrates; Cell respiration and fermentation; The cell cycle; Cell-cell interactions and communication; Transcription; Translation; RNA processing in

Eukaryotes; DNA replication; DNA mutation and repair; Meiosis; Mitosis; and Regulation of Gene Expression.

This information is sometimes available in the course description, but more detail is often found in a course syllabus.

2. The textbook used in the transfer course should be at a comparable level to S. Freeman *et al* (2016) "Biological Science" Sixth Edition, Pearson, ISBN 9780134255033 (eText).
3. Introductory level courses that focus on other biology areas (i.e. anatomy, physiology, ecology, evolution, and/or development) will not be accepted for 03-121 credit. These courses may receive credit for a general biology elective.
4. Students should contact their departmental academic advisor for the transfer credit approval process in their college.

Faculty

NESRINE AFFARA, Assistant Teaching Professor, Carnegie Mellon-Qatar - Ph.D., The Ohio State University; Carnegie Mellon, 2006-

ALISON L. BARTH, Professor - Ph.D., University of California, Berkeley; Carnegie Mellon, 2002-

MOHAMED BOUAOUINA, Associate Teaching Professor, Carnegie Mellon-Qatar - Ph.D., Pierre and Marie Curie University; Carnegie Mellon, 2013-

DANIEL BRASIER, Associate Teaching Professor and Assistant Department Head for Graduate Affairs - Ph.D., University of California, San Diego; Carnegie Mellon, 2012-

MAGGIE BRAUN, Teaching Professor and Associate Dean of Undergraduate Affairs for MCS - Ph.D., University of Pittsburgh; Carnegie Mellon, 2008-

ANDREW BRIDGES, Assistant Professor - Ph.D., Dartmouth College; Carnegie Mellon, 2017-

AMY L. BURKERT, Teaching Professor and Vice Provost for Education - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1997-

EN CAI, Assistant Professor - Ph.D., University of Illinois at Urbana-Champaign; Carnegie Mellon, 2021-

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CARRIE B. DOONAN, Teaching Professor and Director of Undergraduate Laboratories - Ph.D., University of Connecticut; Carnegie Mellon, 1993-

LYNLEY DOONAN, Special Lecturer - Ph.D., University of Pittsburgh; Carnegie Mellon, 2018-

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M. DANNIE DURAND, Associate Professor - Ph.D., Columbia University; Carnegie Mellon, 2000-

CHARLES A. ETTENSOHN, Professor - Ph.D., Yale University; Carnegie Mellon, 1987-

ARYN GITTIS, Professor - Ph.D., University of California, San Diego; Carnegie Mellon, 2012-

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VERONICA F. HINMAN, Professor and Department Head - Ph.D., University of Queensland; Carnegie Mellon, 2006-

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CHRISTINA H. LEE, Associate Professor - Ph.D., University of California, San Francisco; Carnegie Mellon, 2000-

ADAM D. LINSTEDT, Professor - Ph.D., University of California, San Francisco; Carnegie Mellon, 1995-

BROOKE M. MCCARTNEY, Associate Professor – Ph.D., Duke University; Carnegie Mellon, 2003–

NATALIE M. MCGUIER, Assistant Teaching Professor – Ph.D., Medical University of South Carolina; Carnegie Mellon, 2015–

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RUSSELL S. SCHWARTZ, Professor and Head, Computational Biology Department – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2002–

ANNETTE VINCENT, Associate Teaching Professor and Associate Dean for Diversity and Climate, Carnegie Mellon-Qatar – Ph.D., National University of Singapore; Carnegie Mellon, 2012–

JOHN L. WOOLFORD JR., Professor and Co-Director of CNASt – Ph.D., Duke University; Carnegie Mellon, 1979–

AMANDA WILLARD, Special Faculty and Director of Undergraduate Studies – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2020–

STEPHANIE WONG-NOONAN, Assistant Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2016–

IHAB YOUNIS, Associate Teaching Professor, Carnegie Mellon-Qatar – Ph.D., The Ohio State University; Carnegie Mellon, 2005–

ERIC YTTRI, Assistant Professor – Ph.D., Washington University in St. Louis; Carnegie Mellon, 2017–

HUAIYING ZHANG, Assistant Professor – Ph.D., McGill University; Carnegie Mellon, 2019–

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Affiliated Faculty

BRUCE A. ARMITAGE, Professor of Chemistry and Co-Director of CNASt – Ph.D., University of Arizona; Carnegie Mellon, 1997–

PHIL G. CAMPBELL, Research Professor at the Institute for Complex Engineering Systems – Ph.D., Pennsylvania State University; Carnegie Mellon, 1999–

PHILLIP COMPEAU, Assistant Teaching Professor – Ph.D., University of California-San Diego; Carnegie Mellon, 2015–

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WILLIAM F. EDDY, Professor of Statistics – Ph.D., Yale University; Carnegie Mellon, 1976–

T.D. JACOBSEN, Assistant Director and Principal Research Scientist at the Hunt Institute for Botanical Documentation – Ph.D., Washington State University; Carnegie Mellon, 1979–

ROBERT W. KIGER, Distinguished Service Professor and Botany Professor and the History of Science Director and Principal Research Scientist for the Hunt Institute for Botanical Documentation – Ph.D., University of Maryland; Carnegie Mellon, 1974–

CARLETON L. KINGSFORD, Associate Professor of Computational Biology – Ph.D., Princeton University; Carnegie Mellon, 2005–

PHILIP LEDUC, William J. Brown Professor, Mechanical Engineering; Director, Center for the Mechanics and Engineering of Cellular Systems – Ph.D., Johns Hopkins University; Carnegie Mellon, 1999–

CARL R. OLSON, Professor of the CNBC – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

ANDREAS R PFENNING, Assistant Professor of Computational Biology – Ph.D., Duke University; Carnegie Mellon, 2016–

FREDERICK H. UTECH, Principal Research Scientist at the Hunt Institute for Botanical Documentation – Ph.D., Washington University; Carnegie Mellon, 1977–

Adjunct Faculty

AMESH ADALJA, Adjunct Assistant Professor, Senior Scholar-Johns Hopkins Center for Health Security – M.D., American University of the Caribbean School of Medicine; Carnegie Mellon, 2002–

RITA BOTTINO, Adjunct Associate Professor and Principal Investigator at Institute of Cellular Therapeutics - Allegheny Health Network – Ph.D., University of Genova; Carnegie Mellon, 1990–

ROBERT CAMERON, Adjunct Professor, CalTech-Beckman Institute – Ph.D., University of California, Santa Cruz;

YONG FAN, Adjunct Associate Professor and Principal Investigator at Institute of Cellular Therapeutics - Allegheny Health Network – Ph.D., University of Pittsburgh; Carnegie Mellon, 1999–

NICK GIANNOUKAKIS, Adjunct Associate Professor and Principal Investigator at Institute of Cellular Therapeutics - Allegheny Health Network – Ph.D., McGill University in Montreal; Carnegie Mellon, 1997–

JON W. JOHNSON, Professor of Neuroscience at the University of Pittsburgh – Ph.D., Stanford University; Carnegie Mellon, 2006–

KARL KANDLER, Professor of Otolaryngology and Neurobiology at the University of Pittsburgh – Ph.D., University of Tübingen, Germany; Carnegie Mellon, 2006–

CYNTHIA LANCE-JONES, Associate Professor of Neurobiology at the University of Pittsburgh – Ph.D., University of Massachusetts; Carnegie Mellon, 2006–

CYNTHIA M. MORTON, Associate Curator and Head of Botany at the Carnegie Museum of Natural History – Ph.D., New York Botanical Garden/CUNY; Carnegie Mellon, 2002–

JAMES POST, Adjunct Professor, Allegheny Singer Research Institute – Ph.D., University of Pittsburgh School of Public Health; Carnegie Mellon, 2018–

PETER L. STRICK, Co-Director of CNBC and Distinguished Professor of Neurobiology at the University of Pittsburgh – Ph.D., University of Pennsylvania; Carnegie Mellon, 2000–

D. LANSING TAYLOR, President and Chief Executive Officer of Cellumen, Inc. – Ph.D., State University of New York at Albany; Carnegie Mellon, 1982–

MASSIMO TRUCCO, Adjunct Associate Professor and Principal Investigator at Institute of Cellular Therapeutics - Allegheny Health Network – M.D., University of Torino School of Medicine;

KARL WILLIAMS, Adjunct Professor of Otolaryngology and Neurobiology - University of Pittsburgh – M.D., University of Pittsburgh School of Medicine; Carnegie Mellon, 1974–

Emeriti Faculty

PETER B. BERGET, Professor Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1986–

ERIC W. GROTZINGER, Teaching Professor Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1979–

DAVID D. HACKNEY, Professor Emeritus – Ph.D., University of California, Berkeley; Carnegie Mellon, 1978–

CHIEN HO, Professor Emeritus – Ph.D., Yale University; Carnegie Mellon, 1979–

JONATHAN W. JARVIK, Professor Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1978–

LINDA R. KAUFFMAN, Teaching Professor Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1977–

A. JAVIER LOPEZ, Professor Emeritus – Ph.D., Duke University; Carnegie Mellon, 1989–

WILLIAM R. MCCLURE, Professor Emeritus – Ph.D., University of Wisconsin; Carnegie Mellon, 1981–

ROBERT F. MURPHY, Ray and Stephanie Lane Professor of Computational Biology – Ph.D., California Institute of Technology; Carnegie Mellon, 1983–

JOHN F. NAGLE, Professor Emeritus – Ph.D., Yale University; Carnegie Mellon, 1967–

ALAN S. WAGGONER, Professor Emeritus – Ph.D., University of Oregon; Carnegie Mellon, 1999–

JAMES F. WILLIAMS, Professor Emeritus – Ph.D., University of Toronto; Carnegie Mellon, 1976–

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Carnegie Mellon, 1969-

Department of Biological Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

03-050 Study Abroad

Fall

This course number is a placeholder for biological sciences majors who are studying abroad.

03-051 Study Abroad

Spring

This course number is a placeholder for biological sciences majors who are studying abroad.

03-052 Summer Internship

Summer: 3 units

Course Description: The Department of Biological Sciences considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. The Director of Undergraduate Programs (or designee) will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report of their work experience to the Director of Undergraduate Programs (or other designated faculty member). After the reports have been reviewed and approved, a "P" grade will be assigned.

03-116 Phage Genomics Research

Spring: 6 units

Spring Semester: The DNA sequences will be analyzed with bioinformatic tools and compared with those of phages isolated at other locations to identify genes, their organization, the differences that may characterize different phage groups, and how these have arisen during evolution.

Prerequisite: 03-115

03-117 Frontiers, Analysis, and Discovery in Biological Sciences

Fall and Spring: 6 units

In this hands-on laboratory class, students will investigate a current biology problem. Students will read literature articles, design hypotheses, plan and carry out experiments, analyze and interpret data, and design future questions as part of a collaborative research team. In addition, teams will work with faculty and fellow students to understand and explore the relevance of their projects in the field of biology and other disciplines. Finally, teams will communicate results in an oral presentation to peers and faculty. Students will gain research skills, analytical skills, communication skills (both written and oral), and project design skills.

Prerequisites: 03-110 or 03-151 or 03-121

03-118 Beer: A Yeast's Perspective

Fall and Spring: 6 units

This is a combined lecture and laboratory course in which students will investigate the biochemistry of fermentation using strains of yeast commonly used in brewing science. Lectures and readings will cover all necessary information to succeed in the course, including topics like yeast metabolism, fermentation at the micro and industrial levels, and a history of fermentation's influence on society. Lab experiments will investigate yeast growth and fermentation processes in various strains used in brewing, and quantitative assessments of beer at the molecular level. The course puts a focus on microbiology lab techniques and yeast biochemistry; however, no previous lab experience or biology coursework is required, and anyone with an interest in the science behind brewing yeast can succeed in the class.

03-119 Biology for Life Special Topics Micro

Intermittent: 3 units

Special Topics in Biological Sciences Micro Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Spring 2023: Sections W3 and amp; A4: Stayin' Alive: Human Immunity: This course will provide the tools for the layperson to understand how their immune system works to prevent disease and cancer. The course also explains the basis of modern immunotherapies such as vaccines and cancer treatment. Biology at the high-school level is the only requirement. This requirement can be waived after completing a short series of simple on-line modules.

03-120 Biology for Life Special Topics Mini

Fall and Spring: 6 units

Special Topics in Biological Sciences Mini Courses. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Fall 2023 Section A2: Bench Skills with Fluorescent Proteins: In this combined lecture and lab course we will develop our toolkit of molecular biology bench skills in order to identify unknown fluorescent proteins. You will complete experimental work to isolate plasmids, characterize DNA, express fluorescent proteins in bacteria, purify those proteins, and finally identify the unknowns. This course will be a colorful opportunity to practice lab skills before taking required lab classes or starting research. Recommended corequisite of 03-121 Modern Biology.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-121 Modern Biology

All Semesters: 9 units

This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-124 Modern Biology Laboratory

Fall and Spring: 9 units

This laboratory is designed to introduce students to modern concepts in the biological sciences. The experiments illustrate many of the principles covered in 03-121 and 03-230. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

03-125 Evolution

Fall: 9 units

Evolutionary theory is the unifying principle of biology. A good comprehension of the concepts that underlie this theory is therefore important to properly appreciate and understand any biological process. This course is designed for students intending to continue studies in biology so that they may gain an understanding of the evolutionary framework in their more advanced courses, and also non-biology majors who want to extend their knowledge of biology at an introductory level. The lectures will include (i) an examination of the history and development of evolutionary theory, (ii) consideration of some of the facts that have established the theory, (iii) an introduction to the concepts of phylogenetics, (iv) discussion of the patterns and mechanism that lead to the diversity and origins of the groups of life, (v) an introduction to genetics and population genetic theory, and (vi) discussion of and how this applies to natural selection and speciation. The course will also include some more specialist topics, including evolution of development, sexual selection, evolutionary applications to medicine and conservation biology, and genome evolution. Assessment will be based on several in-class exams and quizzes, homework assignments, a written term paper, and a final exam.

03-128 Biology for Life Special Topics

Fall and Spring: 9 units

Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Courses offered under this course number will not require prior knowledge of or exposure to biological sciences and are open to students from any major and class year. Please read individual section descriptions for more information. Summer 1/All 2023: Tropical Ecology at Monteverde Institute. This is a course offered through a study abroad program to Costa Rica. Students will be addressing general questions about tropical ecosystems such as: What are tropical forests? What makes them different than other forests? Where are they and why do global climate patterns result in their geographic distribution? What are the different kinds of tropical forests? What controls the diversity, phenology and successional processes of tropical forests? What are tropical marine ecosystems? This course will also cover specific ecological interactions between organisms such as: seed dispersal, pollination, herbivory, mutualisms, prey-predator interactions in the tropics. Students will also learn about humans in the tropics, both those groups that have evolved and adapted to these environments and the current threats imposed by local/global economic systems. As a part of this course, students will participate in field work and use nature as a laboratory to study the diversity of life forms and interactions between plants, animals, and microorganisms and with the physical environment.

Course Website: https://www.cmu.edu/bio/undergrad/academics/intro_courses.html

03-129 Human Health and Disease

Intermittent: 9 units

The main objective of the course is not only to teach the students how the body works but also to construct a global view of all 9 organ systems and how these organ systems coordinate with each other when homeostasis is challenged. An additional emphasis of this course is the pathophysiological changes that can be associated with each organ malfunction.

03-132 Basic Science to Modern Medicine

Fall and Summer: 9 units

The goal of this course is to give students an understanding of the biology that impacts their everyday lives. Disease can be a tragic part of human life, a fact that is even more apparent in during a global pandemic. To understand how specific diseases like COVID-19 or cancer affect the human body, and how modern medicine can tackle them, this course includes a fundamental study of the basic molecular biology, genetics, and cell biology that underlies disease. This is a topics-based course, with topics chosen to cover aspects of biology and health that students are likely to encounter in their daily lives. The topics for summer 2023 will include COVID-19, genome editing, and cancer. We will explore these topics from both a basic science and a modern medicine perspective. Student's will gain the expertise to critically evaluate media reports about biology and health, and to ask the questions that will help them to make educated decisions in their lives. Key topics: The course will cover at least COVID-19, cancer, and genome editing, in addition to the essential aspects of molecular biology, cell biology, and genetics needed to understand those topics.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-133 Neurobiology of Disease

Spring: 9 units

This course will explore the biological basis of several neurological and neuropsychiatric diseases, with an emphasis on medical diagnostic tools and techniques. It will include discussions of the anatomical basis of neurological diseases as well as recent research into understanding the mechanisms of disease. This course is intended to broaden students' understanding of how diseases are diagnosed and studied. Students will also learn how basic neurological and psychiatric evaluations are conducted. We will discuss neurobiological research to serve as a basis for understanding brain structures and functional alterations in a variety of developmental, degenerative, neurological, and psychiatric disorders.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-135 Structure and Function of the Human Body

Fall: 9 units

Structure and Function of the Human Body is a non-majors course designed to explore fundamental relationships between form and function of the human body. The anatomy and physiology of major organ systems will be studied in the context of normal and disease states. Students will learn about critical biological processes such as the central dogma, membrane diffusion and transport, cell signaling, gas exchange, blood flow, nutrient absorption, blood pH balance, and action potential generation and propagation. Students will then apply this knowledge to understand how organs respond to various inputs in maintaining homeostasis. Hands-on demonstrations will be incorporated to provide a practical framework for the information presented in lectures. At the culmination of the semester, students will gain a broad understanding of how the body systems function at the cellular, tissue and organ levels and be able to relate simple physiological processes to better understand highly prevalent diseases in society.

03-140 Ecology and Environmental Science

Fall: 9 units

Environmental science is a highly interdisciplinary field that integrates knowledge and modes of inquiry from across the sciences to understand some of the most important challenges of the 21st century. This course provides a foundational background in scientific method, critical thinking and problem solving strategies used to study and evaluate the environment. Modules include: principles of ecology and eco-systems, biological diversity, biogeochemical cycles, endangered species management, human population growth, atmosphere, climate and global warming. Assessment will include class attendance, quizzes, individual and small group projects, in class exams. Projects may involve visits to local sites.

03-151 Honors Modern Biology

Fall: 10 units

Honors Modern Biology (03-151) is an honors introductory course. This course has been designed for freshman students with an interest in a major in the biological sciences who have had solid preparation in this field as indicated by the following examinations: SAT II Molecular Biology, AP, or IB Biology. This course will present the concepts and principles necessary for a general understanding of the processes occurring in living cells and is the basis for further study in cell biology, biochemistry, genetics, molecular and developmental biology. While similar core topics will be covered in all sections of Modern Biology, this section will be offered at an accelerated pace, requiring more independent learning. The extra class time this pacing provides will allow the exploration of the molecular basis of life to help students integrate and apply the core principles of biology covered in the course. THIS SECTION IS RESERVED FOR INCOMING FIRST-YEAR MCS STUDENTS.

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-161 Molecules to Mind

Spring: 9 units

This course provides a depth-first approach to understanding neuroscience. We will begin with a clinical focus on neuroanatomy, introducing students to some basic neurological diagnostic techniques. We will then explore the biological basis of neuronal function and link the function of individual neurons to a broader context of neural systems. This will be done in the context of primary literature. Students who complete this course will therefore have an understanding of research methods and be prepared to evaluate scientific literature. The course will have a strong focus on the biological and cellular basis of neuronal excitability and also give students significant, in depth exposure to the function of synapses and their plasticity. Finally, the course will give students an in depth look at sensory and/or motor systems by focusing on one system in particular.

03-201 Undergraduate Colloquium for Sophomores

Fall

The purpose of this seminar series is to update biology undergraduates about university and departmental functions, seminars, etc. that are pertinent or useful. In addition, research talks by faculty and undergraduates will be used to introduce students to the research being conducted in faculty laboratories. Additional topics may include graduate and medical school applications, career options, topics in the press, and important scientific discoveries.

03-202 Undergraduate Colloquium for Sophomores

Spring

Missing Course Description - please contact the teaching department.

03-206 Biomedical Engineering Laboratory

Fall and Spring: 9 units

This laboratory course is designed to provide students with the ability to make measurements on and interpret data from living systems. The experimental modules reinforce concepts from 42-101 Introduction to Biomedical Engineering and expose students to four areas of biomedical engineering: biomedical signal and image processing, biomaterials, biomechanics, and cellular and molecular biotechnology. Several cross-cutting modules are included as well. The course includes weekly lectures to complement the experimental component. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Notes: This course number is reserved for students who are CIT majors and registered with the HPP program. If you require a biology lab for pre-health admissions requirements, register for 42-203 and Dr. Sang Chalacheva will work with students once the semester begins to register for 03-206 instead of 42-203. Priority for enrollment will be given to students who have declared the Additional Major in Biomedical Engineering. Prerequisites: (03-151 or 03-121) and 42-101

03-210 Independent Study

Fall and Spring

Students will read papers from the original literature under the direction of a faculty member. Students will be required to demonstrate mastery of the readings by discussions with the sponsoring faculty member, oral presentations, or writing of one or more papers summarizing and extending the information in the readings. If appropriate, students may write a program(s) to satisfy this last requirement. A student may take this course only once. This is a mini format course. Special permission required. **Students MUST contact bio-ugrad@andrew.cmu.edu and complete the application form in order to participate and register.**

03-220 Genetics

Fall: 9 units

The mechanisms of transmission of inherited traits in viruses, bacteria, fungi, plants and animals are discussed. Molecular mechanisms of gene expression and gene regulation are analyzed. Recombinant DNA and its applications in genetic analysis, biotechnology, forensics, agriculture, medicine, and the pharmaceutical industry are presented. Special topics in human genetics are considered, such as the genetics of cancer. Principles and methods for the study of developmental genetics, population genetics and complex traits are also introduced. Prerequisites: 03-121 or 03-151

03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis

Spring: 9 units

Scientific and technical advances in genetics have accelerated dramatically since the draft human genome sequence was published in 2001. The development of massively parallel DNA sequencing and associated technologies has transformed the way we approach genetic questions. Contemporary genetics is increasingly concerned with generating, processing and analyzing vast amounts of data to extract information about genetic variation, expression, interactions and associations. At the same time, comparative genomics, bioinformatic and reverse genetic methods are transforming the way in which gene functions are investigated, while the development of powerful methods for precise modification of genomes is opening the way to cell- and gene-based therapies for disease. In parallel, the promise of precision or personalized medicine is predicated on advances in understanding of complex traits, genetic interactions and networks. These and other topics will be covered following a review of basic principles of gene structure and expression, the fundamental principles of Mendelian genetics, and their underpinnings in cellular mechanisms for the replication, recombination and transmission of genetic material. Although the topics overlap extensively with 03220 (Genetics), they will be presented at a more advanced level, with a greater emphasis on current methods of quantitative and statistical analysis. This course is recommended for students with a particular interest in emerging technologies for analysis of human genetics, genomics, gene therapy and precision medicine. Prerequisites: (03-121 Min. grade B or 03-151 Min. grade B) and (36-225 Min. grade C or 21-124 Min. grade C or 36-200 Min. grade C or 15-359 Min. grade C or 15-259 Min. grade C or 36-218 Min. grade C or 36-201 Min. grade C or 36-247 Min. grade C or 36-217 Min. grade C)

03-230 Intro to Mammalian Physiology

Spring: 9 units

This course has been designed to explore human physiology at an introductory level. Emphasis will be placed on the physiological processes in an organ system framework and focus on a wide range of pertinent clinical topics. Our aim is to instill in you a deeper appreciation for the complexity and beauty of the human body, and most importantly, to motivate you to carry away physiological principles that you may need later in your profession or simply may be relevant to a real-world situation. Prerequisites: (03-151 or 03-121) and (03-231 or 03-232)

03-231 Honors Biochemistry

Spring: 9 units

This course provides an introduction to molecules and processes found in living systems. Amino acids, sugars, lipids and nucleotides and their corresponding higher structures, proteins, polysaccharides, membranes and nucleic acids are studied. Kinetics and mechanisms of enzymes as well as elementary metabolic cycles and the energetics of biological systems are studied with a quantitative approach. Prerequisites: 03-151 or 03-121

03-232 Biochemistry I

Spring: 9 units

This course provides an introduction to the application of biochemistry to biotechnology. The functional properties of amino acids, nucleotides, lipids, and sugars are presented. This is followed by a discussion of the structural and thermodynamic aspects of the organization of these molecules into higher-order structures, such as proteins, nucleic acids, and membranes. The kinetics and thermodynamics of protein-ligand interactions are discussed for non-cooperative, cooperative, and allosteric binding events. The use of mechanistic and kinetic information in enzyme characterization and drug discovery are discussed. Topics pertinent to biotechnology include: antibody production and use, energy production in biochemical systems, expression of recombinant proteins, and methods of protein purification and characterization. The course is an alternate to 03-231. Prerequisites: 06-223 or 09-107 or 06-221 or 09-105

03-320 Cell Biology

Fall: 9 units

This course provides descriptive information and mechanistic detail concerning key cellular processes in six areas: membrane function, protein targeting, signaling, cytoskeleton, cell division, and cell interaction. An attempt is made to introduce the methodology that was used to obtain this information and to discuss how our understanding of these processes relates to the treatment of human disease. Prerequisites: (03-151 or 03-121 or 03-120) and (03-231 or 03-233 or 03-232)

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-327 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Intermittent: 9 units

An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome. Prerequisites: 03-151 or 03-121

Course Website: <http://www.cs.cmu.edu/~durand/Phylogenetics/>

03-342 Introduction to Biological Laboratory Practices

Fall: 1 unit

This course is designed for students in the BSA degree program. It is designed to be an introduction to basic laboratory practices. The course will introduce biological and chemical safety training and basic laboratory practices. Techniques of solution preparation and titration, pipetting, UV/VIS spectroscopy, and quantitation of biological compounds will be covered.

03-343 Experimental Techniques in Molecular Biology

Fall: 12 units

This laboratory course is designed to teach experimental methods of modern biology. Experiments in microbial genetics, molecular biology and eukaryotic genetics are performed. Emphasis is placed on understanding and applying the biological principles of each experiment. This course is designed to be taken during the junior year and is intended to prepare students for undergraduate research. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: (03-231 or 03-232) and (qc211 or 09-223 or 09-208 or 09-222)

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html>
(<http://www.cmu.edu/bio/undergrad/courses/>)

03-344 Experimental Biochemistry

Spring: 12 units

This course is designed to be taken as a sequel to 03-343. Experiments cover a variety of methods for investigating the structure and function of biological molecules. Experimental methods with proteins, enzyme kinetics, lipids, spectroscopy, and isolation and quantization of biological molecules are covered. During several experiments, students design their own projects. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: 03-343 and (03-231 or 03-232)

03-345 Experimental Cell and Developmental Biology

Spring: 12 units

This laboratory is designed to teach concepts and experimental methods in cell and developmental biology. Students work with a variety of organisms to examine how cells traverse development from rapidly dividing, undifferentiated cells, through cell commitment and the establishment of spatial and temporal patterns of gene expression, to the specific characteristics and responses of terminally differentiated cells. The course makes extensive use of video microscopy with phase contrast, DIC and fluorescence microscopes. Biochemical, immunological and molecular biological techniques are used to probe the molecules and processes of cells undergoing development. Experimentation using living organisms and/or their tissues, cells or molecules is an essential component of this course.

Prerequisites: 03-343 and (03-232 or 03-231) and (03-240 or 03-320)

03-346 Experimental Neuroscience

Intermittent: 12 units

This laboratory is designed to teach concepts and experimental methods in neurobiology. Students work with a variety of organisms to study the anatomy, function, and development of the nervous system. Immunological, molecular, biochemical, and ballistic labeling techniques are used to examine the gene expression and structure in the mature and developing nervous system. Students study the function of neurons through neurophysiological techniques in invertebrates and computer simulation. This course makes extensive use of video microscopy and phase contrast, DIC, and fluorescence microscopes.

Prerequisites: (03-240 or 03-320) and 03-362 and 03-343

03-350 Developmental Biology

Spring: 9 units

How does a complex, multicellular organism arise from a single cell? How do cells with identical genomes acquire distinctive properties? What are the medical consequences of abnormal embryonic development? How does regeneration occur? How has evolution modified developmental programs to produce different body plans? These are some of the central questions in the field of developmental biology. This course serves as an introduction to current concepts and experimental approaches in this rapidly advancing field. Topics in the course include genomics, differential gene expression, cell signaling, cell movements, tissue morphogenesis, stem cells, human development, and regeneration. The course examines the genes and signaling pathways that control development and the role that mis-regulation of these pathways plays in human disease.

Prerequisites: 03-240 or 03-320

03-351 Computation and Biology Integrated Research Lab

Fall: 9 units

Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both.

Prerequisites: 03-343 or 03-124 or 03-117 or 15-112

03-360 Genomics and Epigenetics of the Brain

Fall: 9 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in genomic technology are in the process of revolutionizing how we conduct molecular biology research. These new techniques have given us an appreciation for the role that epigenetics modifications of the genome play in gene regulation, development, and inheritance. In this course, we will cover the biological basis of genomics and epigenetics, the basic computational tools to analyze genomic data, and the application of those tools to neuroscience. Through programming assignments and reading primary literature, the material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.

Prerequisites: 03-330 or 03-220

03-362 Cellular Neuroscience

Fall: 9 units

Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of cellular and molecular neuroscience ranging from molecules to simple neural circuits. Topics covered will include the properties of biological membranes, the electrical properties of neurons, neural communication and synaptic transmission, mechanisms of brain plasticity and the analysis of simple neural circuits. In addition to providing information the lectures will describe how discoveries were made and will develop students' abilities to design experiments and interpret data.

Prerequisites: 03-161 or 85-219 or 42-202 or 03-230 or 03-320

03-363 Systems Neuroscience

Spring: 9 units

Modern neuroscience is an interdisciplinary field that seeks to understand the function of the brain and nervous system. This course provides a comprehensive survey of systems neuroscience, a rapidly growing scientific field that seeks to link the structure and function of brain circuitry to perception and behavior. This course will explore brain systems through a combination of classical, Nobel prize-winning data and cutting edge primary literature. Topics will include sensory systems, motor function, animal behavior and human behavior in health and disease. Lectures will provide fundamental information as well as a detailed understanding of experimental designs that enabled discoveries. Finally, students will learn to interpret and critique the diverse and multimodal data that drives systems neuroscience.

Prerequisites: 03-320 or 03-230 or 42-202 or 03-240 or 85-219 or 03-161

03-365 Neural Correlates of Learning and Memory

Spring: 9 units

This course will examine the biological substrates of learning, memory, and behavioral adaptation. The focus will be on addressing how neural circuits change during new skill acquisition and adapt to variations in the environment. An introduction to experience-dependent changes in neural structure and function, in addition to behavioral learning paradigms, will be provided. Then we will consider the ways in which specific changes in biological substrates give rise to the emergent properties that drive behavioral adaptation, followed by in depth coverage of deciphering which biological substrates constitute a lasting memory trace. Finally, the concept of age-dependent learning will be examined. Concepts and specific examples will come through reading of primary literature and selected readings from advanced texts.

Prerequisites: 03-161 or 85-219 or 03-240 or 03-320

03-366 Neuropharmacology: Drugs, Brain and Behavior

Fall: 9 units

This course is designed to give students a comprehensive understanding of the major neurotransmitter systems in the brain. Students will explore approaches to understanding how various neurotransmitters function in sensory and motor systems as well as how they are modulated by endogenous and exogenous agents. The exploration will include basic principles of neural communication, signal transduction and second messenger systems, main classes of neurotransmitters, and the effects of medications and drugs of abuse. In terms of sensory and motor systems, student will learn how different neurotransmitters affect different aspects of systems neuroscience and how a single neurotransmitter can have multiple roles in different systems. Students will learn how these processes affect the endocrine system, neuroinflammatory responses, addictive behaviors, and neurotoxic or degenerative conditions.

Prerequisites: 03-133 or 03-362 or 03-231 or 03-232

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)**03-380 Virology**

Fall: 9 units

The concepts and methods of virology are covered, with emphasis on animal viruses, within the framework of cell biology, genetics, molecular biology, immunology, pathology, and epidemiology. The strategies that a wide variety of different DNA and RNA viruses, including some new and emerging ones, use to replicate and express their genomes during infection of host cells will be examined in some detail. The effects that viruses inflict on these cells will also be examined, as will some of the host cell responses generated by such virus-cell interactions, including interferon induction, the antiviral response generated by interferon, and oncogenic transformation. In addition, an overview of procedures used for prevention and treatment of viral diseases via vaccines and antiviral drugs, respectively, will be presented, as will a brief discussion of viroids and prions, and the characteristics of these agents which distinguish them from viruses.

Prerequisites: 03-240 or 03-320

03-390 Molecular and Cellular Immunology

Spring: 9 units

This is a course that covers the fundamentals of cellular and molecular immunology in a comprehensive manner. The objective of this course is to introduce the students to the immune system, the cells that constitute it, their ontogeny, their structure, activities and responses to stimuli and the systems/signals that integrate these cells into a coherent functional entity. Additionally, the course will demonstrate where, when, and how, the immune system responds in pathologic states, how its cells can themselves become the causes of pathologies, and how medical science targets and uses the immune system to prevent and treat a wide range of diseases.

Prerequisites: (03-231 or 03-232) and (03-320 or 03-240)

03-391 Microbiology

Spring: 9 units

The course provides introductory level microbial science and molecular biology that is aimed for students from all disciplines of natural science. It covers microbiology, genetics, genomics, as well as bacterial, fungal, and protozoan pathogenesis. Topics include: the human microbiome, genome sequencing, gene transfer across species, virulence, and drug resistance.

Prerequisites: 03-232 or 03-231

03-409 Applied Cell Biology

Intermittent: 3 units

The course provides a hands-on experience in biology lab to conduct experiments, collect and analyze scientific data with the purpose of using the data to infer biological principals. Students will learn the details of western blot technique, commonly used in biology labs. In addition, they will apply the technique to study how insulin triggers specific signaling in target cells. This lab module will reinforce the students' understanding of material seen in Cell Biology lecture course (co-requisite 03-240) and will prepare them for future lab courses.

03-410 Special Topics in Biological Sciences

Fall and Spring: 9 units

Special Topics in Biological Sciences. Topics will vary depending on the semester and instructor. Please read the individual section descriptions for more information.

Prerequisites: 03-231 or 03-232

03-411 Topics in Research

Fall

During the year students attend weekly seminars given by outside speakers or members of the Biology Department on current research topics in modern biology; some seminars outside of the department may be substituted.

03-412 Topics in Research

Spring

Students attend weekly seminars by scientists from other universities who have been invited by the Department of Biological Sciences to present their research to our faculty, postdoctoral scientists, graduate students, and staff. A written response to questions about the seminar is prepared by each student during the seminar and turned in to the instructor at the end of the seminar.

03-435 Cancer Biology

Fall: 9 units

Cancer affects roughly 1 in 3 people worldwide, and originates from both hereditary as well as environmental causes. Its prevalence makes it practically inescapable. Its of great relevance from both scientific and sociocultural perspectives. This course aims to examine various hallmarks of the biology of cancer while exploring novel concepts that challenge our understanding of cell biology. From the perspective of a cancer cell, we will learn about basic concepts of cell division, DNA replication, cell signaling, cell cycle control, cell metabolism, the regulation of gene expression in human cells, oncogenes, tumor suppressor genes, mutations, the process of metastasis, cancer diagnosis, cancer treatments and ethical questions surrounding treating patients, the epidemiology of cancer including prevalence and historical trends in diagnosis, as well as social impacts of a cancer diagnosis. Students will also explore the primary literature and scientific review articles to better understand research and methods of investigation into the cellular and molecular processes of tumorigenesis. This course will include interactive lectures, guest speakers, and in class discussion exercises aimed at building class participation and association, as well as confidence in public speaking about the sciences. Given the well-documented link between stress and cancer, there will also be a small component aimed at making students aware of health and wellness, such as reducing stress and anxiety.

Prerequisites: 03-330 or 03-220 or 03-221

03-439 Introduction to Biophysics

Fall: 10 units

Biological physics, or the physics of living systems, is an exciting interdisciplinary frontier of physics that aims to understand the phenomenon of life using concepts and tools from Physics. This intermediate level course will introduce the general concepts and principles underpinning the physical behavior of living systems, from the dynamics of proteins and molecules to collective behavior of living cells and organisms. The course will develop key physics concepts that are most vital to biological processes, including energy conversion, information transfer, mechanics of movement, statistical phenomena, and fluid flow. We will apply these physics concepts to demonstrate how biological systems function, build simplified mathematical models to predict behavior, and use experimental data to inform and test models. The integration of biological phenomena, physical concepts, mathematical modeling, and analysis of experimental data represents an entirely new mode of learning, based on strategies adopted in research. These strategies will break traditional disciplinary barriers between physics and biology. The students will be expected to gain an intuitive grasp of ways to: frame the physical problem, identify appropriate theoretical frameworks, analyze experimental data, and ways to generalize and to understand the dependence of biophysical phenomenon on time and length scales. No prior knowledge of biology is expected. This class is offered in Fall of even years (e.g. Fall '22, 24, etc.)

Prerequisites: (03-151 or 03-121) and (33-122 or 33-112 or 33-142 or 33-107 or 33-152 or 33-132)

03-442 Molecular Biology

Fall: 9 units

The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

Prerequisites: 03-221 Min. grade B or 03-220 Min. grade B or 03-330 Min. grade B

Course Website: <http://www.cmu.edu/bio/undergrad/courses/index.html> (<http://www.cmu.edu/bio/undergrad/courses/>)

03-445 Undergraduate Research

Fall and Spring

Students may investigate research problems under the supervision of members of the faculty. Permission of a faculty advisor required. **Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and register.** BIO MAJORS: The Biology Undergraduate Office will send out the paperwork to you on the first day of classes each semester. Paperwork and research mentor approval will be due the Friday before the add deadline. NON BIO MAJORS: Please contact the office (bio-ungrad@andrew.cmu.edu) to request the updated form.

03-451 Advanced Developmental Biology and Human Health

Fall: 9 units

This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty. Instructor permission is required to register. Please contact Dr. Etensohn and lt;ettensohn@cmu.edu and gt;. Prerequisites: (03-240 Min. grade B or 03-320 Min. grade B) and (03-220 Min. grade B or 03-330 Min. grade B)

03-511 Computational Molecular Biology and Genomics

Fall: 9 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology.

Prerequisites: (03-121 or 03-151) and 15-122

Course Website: <http://www.cs.cmu.edu/~durand/03-711/>**03-545 Honors Research**

Spring: 9 units

This semester of research consists primarily of research and preparation of an acceptable written thesis. Oral presentation and defense of the thesis research will be required. This course ordinarily will be taken in the second semester of the senior year. Permission of the research advisor required.

Students MUST contact bio-ungrad@andrew.cmu.edu and complete the application form in order to participate and register.

Prerequisite: 03-445

03-600 Biotechnology or Biopharmaceutical Engineering Internship

All Semesters

This course allows a student to gain biotechnology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice biotechnology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-601 Computational Biology Internship

All Semesters

This course allows a student to gain computational biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice computational biology skills acquired in the classroom. Typically, students seek and secure their own internships.

03-602 Quantitative Biology Internship

All Semesters

This course allows a student to gain quantitative biology experience in a "real-world" setting. Internships vary widely in scope, but common to all is the chance to practice quantitative biology skills acquired in the classroom. Typically, students seek and secure their own internships. Students are required to write written reflections summarizing their internship work and submit those to the course instructor.

03-603 Applied Professional Skills for Computational Biologists

Fall and Spring: 3 units

This course gives Masters in Computational Biology students the opportunity to refine the professional skills necessary for a successful career in industry. This course, required for students completing the "Applied Study" option in the MS in Computational Biology program, provides opportunities to connect with computational biology professionals as part of industry outreach. The course will also include additional, customized review of application materials.

03-604 Professional Skills for Biotechnology, Quantitative & Computational Biology

Fall: 3 units

This course gives Masters students in Biological Sciences and related fields the opportunity to develop the professional skills necessary for a successful career in either academia or industry. The first set of topics will include assistance with elevator pitches, interview preparation, resume and cover letter writing, and presentation skills. The course will also guest speakers to connect with students professionally and to provide students with perspectives from within industry on regulatory compliance issues. The course is pass/fail only.

03-622 Modern Biology

Fall: 9 units

This is an introductory course that provides the basis for further studies in biochemistry, cell biology, genetics and molecular biology. This course emphasizes the chemical principles underlying biological processes and cell structures as well as the analysis of genetics and heredity from a molecular perspective. This is the introductory biology course for all science and non-science majors.

03-699 MS Research

All Semesters

A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. Students who are writing an honors thesis should enroll in 03-700 instead.

03-700 MS Honors Thesis Research

All Semesters

A student enrolled in this course conducts an independent investigation on a project in a faculty advisor's lab. The project is selected from a major area of research study with the advice and approval of the faculty advisor. This course is required of students who are enrolled in the Master of Science program and wish to write and defend a thesis. This course is only for students who are writing an honors thesis.

03-709 Applied Cell and Molecular Biology

Fall: 12 units

The purpose of this course is to review key cellular and molecular phenomenon in biological pathways with strong emphasis on latest experimental techniques used in applications including but not limited to disease diagnosis, therapeutics, large-scale genomic and proteomic analysis. Knowledge gained from this course will be both conceptual and analytical. Students will periodically write extensive research reports on select topics and give oral presentations on a select few, while critically analyzing primary literature.

03-711 Computational Molecular Biology and Genomics

Fall: 12 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. This course provides an in-depth treatment of the algorithmic foundations of computational molecular biology.

Prerequisites: (03-121 or 03-151) and 15-122

Course Website: <http://www.cs.cmu.edu/~durand/03-711/>**03-713 Bioinformatics Data Integration Practicum**

Spring: 6 units

This course provides a hands-on, self-directed experience dealing with biological data and integrating it to produce software and analyses that are of use to biologists. Data are taken from a variety of sources, including academic research labs, large scale public genomics projects and data from private industry partners. Students will be given a project and asked to design a solution using a combination of existing tools and their own developed software.

03-727 Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method

Fall: 12 units

An advanced introduction to the evolutionary concepts and bioinformatic skills that are central to molecular, cell, developmental, and microbiology. Proteins that share common ancestry also share functional properties. This is the guiding principle of model organism research and sequence-based bioinformatics. Evolutionary trees (phylogenies) and multiple sequence alignments provide evidence for predicting structural and functional constraints, sites of molecular interaction, and residues that confer functional specificity. In 2021, phylogenetics is emerging as an essential technique in metagenomics, cancer, and infectious disease, driven by technological advances such as high through-put sequencing and single-cell phenotyping. This course covers both the conceptual foundation and the practical skills of evolutionary bioinformatics. Students will acquire the "tree thinking" skills required for critical interpretation of phylogenetic analyses and figures in the literature and a rigorous understanding of phylogenetic inference methods. Theoretical knowledge will be complemented by hands-on experience with sequence data repositories, bioinformatic tools for database retrieval, sequence analysis, and tree building. Students will walk out of the course with the knowledge required to apply those tools correctly to messy, genuine data sets, and the ability to evaluate alternate hypotheses in light of these bioinformatic analyses. Students with a range of computational backgrounds are welcome.

Course Website: <http://www.cs.cmu.edu/~durand/Phylogenetics/>**03-728 Genome Editing Biotechnology**

Fall: 6 units

How can we create genetically engineered cells, animals, plants, and even humans? This course will focus on the technologies that enable genome modification, with an emphasis on the recently developed CRISPR-Cas9 system. Specific topics will include an introduction to CRISPR technology and its history; DNA double strand break repair; Off target effects; Gene regulator CRISPRs; Alternate technologies; Ethics of modifying our genomes; Applications - cell screening; Applications - organism engineering; Applications - anti-HIV and immunotherapy; Overview of Gene therapy. Student in-class presentations will cover late-breaking topics and specific areas of student interest.

Prerequisites: 03-709 or 03-621 or 03-221 or 03-220

03-729 Entrepreneurship and protein-based drug development

Spring: 6 units

This is a course for students with background in biochemistry who want to learn about business opportunities and advances in protein-based treatments. As protein-based biologic drugs become more and more prevalent understanding the role of protein-protein interactions is vital for both design and production of biologic drugs. We will focus on the fundamentals of protein-interactions, giving examples of protein-protein interactions in important cellular pathways. We will also focus on how protein-protein interactions are used in the processing of biologic drugs, where antibody-Protein A interactions are key for the purification of antibody-based biologics. We will study case-studies of how the pharmaceutical industry develops biologics from conception, through FDA approval, to mass production.

Prerequisites: 03-709 or 03-231

03-730 Advanced Genetics

Spring: 12 units

This course considers selected current topics in molecular genetics at an advanced level. Emphasis is on classroom discussion of research papers. Topics are subject to change yearly. Examples of past topics include: nucleocytoplasmic trafficking of RNA in yeast, genome imprinting in mammals, molecular genetics of learning and memory in *Drosophila*, viral genomics, using yeast as a model system to study the molecular basis of human neurodegenerative diseases, and CRISPR/Cas9 genome editing.

Prerequisites: (03-221 Min. grade B or 03-220 Min. grade B or 03-330 Min. grade B) and (03-742 or 03-442)

03-738 Synthetic Biology

Fall: 6 units

This course discusses the design of artificial biological parts or systems for research, engineering and medical applications. The course is divided into two parts: top-down and bottom-up synthetic biology. In top-down synthetic biology, engineering of cells with new functions or new products with metabolic and genetic engineering techniques such as circuit building, directed evolution, CRISPR-Cas9 will be covered. In bottom-up synthetic biology, the assembly of molecules to obtain a specific biological output such as in vitro reconstitution of cellular machinery, cell free protein expression system and construction of artificial cells will be discussed.

Prerequisites: 03-231 or 03-232

03-741 Advanced Cell Biology

Spring: 12 units

This course covers fourteen topics in which significant recent advances or controversies have been reported. For each topic there is a background lecture by the instructor, student presentations of the relevant primary research articles and a general class discussion. Example topics are: extracellular matrix control of normal and cancer cell cycles, force generating mechanisms in trans-membrane protein translocation, signal transduction control of cell motility, and a molecular mechanism for membrane fusion.

Prerequisites: (03-240 or 03-320) and (03-231 or 03-232)

03-742 Advanced Molecular Biology

Fall: 12 units

The structure and expression of eukaryotic genes are discussed, focusing on model systems from a variety of organisms including yeast, flies, worms, mice, humans, and plants. Topics discussed include (1) genomics, proteomics, and functional proteomics and (2) control of gene expression at the level of transcription of mRNA from DNA, splicing of pre-mRNA, export of spliced mRNA from the nucleus to the cytoplasm, and translation of mRNA.

03-744 Membrane Trafficking

Spring: 9 units

While the focus of this course is to analyze membrane/protein traffic along both the biosynthetic and endocytic pathways, our general goal is to teach students how to read and interpret the literature. In particular, we emphasize the conclusions and discuss their validity. The course is updated each year to include topics in which new and interesting developments have occurred. Emphasis is placed on how membrane traffic is regulated and where applicable how it is disrupted or subverted during disease processes. The course is of general interest to students, fellows, and faculty interested in cell biology, immunology, neurobiology, pharmacology and virology.

Prerequisites: 03-320 or 03-240

03-747 Proposal Preparation and Peer Review

Fall: 4 units

The concise and clear presentation of an experimental research plan is an essential skill for research scientists. This mini course is designed to introduce 2nd year students to the structure and preparation of a structured research proposal as well as formalize instruction in professional standards in research ethics, CV preparation, and scientific writing and data presentation. Course material is taken from actual grant proposals and previous years' qualifying exam proposals, as well as primary research publications and faculty grant proposals. The course is highly interactive, and students are required to participate in review of each others' work throughout the duration of the course. Coursework is expected to form the basis of the Ph.D. qualifying exam proposal in the winter of the second year.

03-750 Graduate Seminar

Fall and Spring: 1 unit

Each semester, all Department of Biological Sciences graduate students are required to register for and attend the weekly departmental Research Seminar (03-750; 1 unit). Graduate students are strongly urged to meet the speakers to broaden their knowledge of cutting-edge biological science, to discuss career paths and strategies and to make useful contacts; the faculty host can arrange group meetings for interested students.

03-751 Advanced Developmental Biology and Human Health

Fall: 12 units

This course will examine current research in developmental biology, focusing on areas that have important biomedical implications. The course will examine stem cell biology, cellular reprogramming, cell signaling pathways, tissue morphogenesis, and genetic/developmental mechanisms of birth defects and human diseases. Emphasis will be placed on the critical reading of recent, original research papers and classroom discussion, with supporting lectures by faculty. Instructor permission is required to register. Please contact Dr. Etensohn and lettensohn@cmu.edu and gt;

Prerequisites: (03-320 or 03-240) and (03-220 or 03-330)

03-755 Graduate Research Seminar

Fall and Spring: 3 units

Each semester, all Departmental of Biological Sciences graduate students are required to register for and attend the weekly departmental Journal Club (Graduate Research Seminar 03-755; 3 units) during which students and faculty members give 25-minute presentations. Second-year students present a research paper or topic from the literature, and more senior students present their research results; typically, graduate students give four Journal Club presentations during their time in the department. Each succeeding year those students who speak at the Departmental Retreat or who are graduating by May of their fifth year are not required to present at Journal Club that year.

03-756 Graduate Independent Study

Fall and Spring

N/A

03-762 Advanced Cellular Neuroscience

Fall: 12 units

This course is an introductory graduate course in cellular neuroscience. As such it will assume little or no background but will rapidly progress to discussions of papers from the primary literature. The structure of the course will be about half lectures and half discussions of new and classic papers from the primary literature. These discussions will be substantially led by students in the course. Topics covered will include ion channels and excitability, synaptic transmission and plasticity, molecular understanding of brain disease and cell biology of neurons. Assessment will be based on class participation, including performance on in-class presentations and a writing assignment.

03-763 Advanced Systems Neuroscience

Spring: 12 units

This course is a graduate version of 03-363. Students will attend the same lectures as the students in 03-363, plus an additional once weekly meeting. In this meeting, topics covered in the lectures will be addressed in greater depth, often through discussions of papers from the primary literature. Students will read and be expected to have an in depth understanding of several classic papers from the literature as well as current papers that illustrate cutting edge approaches to systems neuroscience or important new concepts. Use of animals as research model systems will also be discussed. Performance in this portion of the class will be assessed by supplemental exam questions as well as by additional homework assignments.

Prerequisites: 03-762 or 03-151 or 03-121 or 03-362

03-776 Molecular Techniques for Bioprocessing

Spring: 6 units

This course is the first in a sequence of two lab minis (03-776 and amp; 06-777) required for an MS degree in Biotechnology and Pharmaceutical Engineering. It is designed to teach you techniques used in molecular biology research, specifically those involved with upstream bioprocessing. In addition, you will further develop your skills in experimental design, quantitative reasoning, and critical analysis. While specific experiments may change from semester to semester, core topics include cloning techniques (plasmid isolation and characterization, PCR, restriction enzyme digests, gel electrophoresis) and cell culture (bacteria and mammalian). Experiments are designed to generate a eukaryotic cell line expressing a protein of interest. The follow-up lab, 06-777 for downstream bioprocessing, will build on the techniques and share some reagents.

Prerequisite: 03-709

03-791 Advanced Microbiology

Spring: 12 units

This course will use both lectures and current research literature in the area of Microbiology and Infectious Diseases to introduce such topics as prokaryotic cytoskeletal functions, the human microbiome and its impact, metabolic engineering, transposon mutagenesis for gene function elucidation, synthetic genome construction and applications, pathogenicity islands, functional and expression-based identification of pathogenicity determinants, horizontal gene transfer, regulatory RNAs, biofilm formation quorum sensing, and antimicrobial drug development.

03-871 Structural Biophysics

Fall: 12 units

This course (MB-1) is the first-semester core course for the joint CMU-Pitt graduate program in Molecular Biophysics and Structural Biology (MBSB). The physical properties of biological macromolecules and the methods used to analyze their structure and function are discussed in in-depth lectures. Topics covered include: protein architecture and folding; nucleic acid structures and energetics; structure determination by X-ray crystallography and NMR; optical spectroscopy with emphasis on absorption and fluorescence, NMR spectroscopic methods; other methods to characterize proteins and protein-ligand interactions, such as mass spectrometry, calorimetry, single-molecule manipulation and measurements, and surface plasmon resonance. Sufficient detail is given to allow the student to critically evaluate the current literature.

Prerequisites: (03-231 or 03-232) and (09-214 or 09-344) and (21-120 or 21-122)

03-900 Doctoral Thesis Research

All Semesters

Doctoral Thesis Research consists of an independent investigation on a project selected from a major area of research study with the advice and approval of the faculty advisor.

Department of Chemistry

Bruce Armitage, Department Head

Karen H. Stump, Director of Undergraduate Studies

Location: Doherty Hall 1316
www.chem.cmu.edu (<http://www.chem.cmu.edu>)

Mission Statement

Chemistry at Carnegie Mellon University is committed to making advances in the molecular sciences with lasting impact on foundational knowledge while tackling critical global challenges including sustainability, health, and quality of life.

Chemistry is an area of science involved with the study of the properties and reactions of substances ranging from living cells to subatomic particles. It is at the center of many scientific and technical fields, providing the fundamental knowledge and tools needed to address many of society's needs and to explore the unknown. Fields as diverse as genetic engineering, materials science and nanotechnology look to chemistry when they look to the future, for that is where the ultimate in understanding — the molecular level — resides.

Flexible Career Options

The chemistry profession is extraordinarily diverse, with career opportunities available in the chemical, petroleum, renewable energy, nuclear power, novel polymeric materials, metals, personal care and pharmaceutical industries, among many others. Chemistry plays an increasingly important role in the rapidly expanding biomedical and biotechnology industries. In addition to careers in industry and academia, many chemists find rewarding careers in the public sector in the laboratories of the National Institutes of Health, the Food and Drug Administration, the Environmental Protection Agency, the National Institute of Standards and Technology, and the Department of Energy as well as in consulting. Chemistry graduates also find employment in technical fields unrelated to science but where their problem solving and communication skills are highly valued.

Chemistry is a particularly suitable major for pre-medical and other pre-health profession students. Medical schools look favorably on the rigorous reasoning skills chemists develop, as evidenced by an excellent record for student admission to advanced education in these areas. An increasing number of our graduates are seeking careers in dentistry, pharmacy or pharmacology in addition to medicine. The Health Professions Program advises all Carnegie Mellon students considering careers in health fields. (See Health Professions Program description in this catalog for more information.) Chemistry is also excellent preparation for careers in law, especially for those with an interest in specializing in patent, intellectual property or environmental law. The curriculum has the flexibility to allow these students to participate in the CMU Washington Semester Program with the possibility of an internship in science policy should they desire. Students interested in industrial careers often combine their chemistry program with undergraduate courses in business administration or eventually go on to study for an M.B.A.

Any graduating class in chemistry reflects this diversity in career paths.

Some recent examples from the class of 2020 are alumni working as software engineers for Bloomberg in London and at MasterCard, in Healthcare Technical Services at Epic Systems, as a Research Scientist at Eli Lilly and as a Clinical Research Assistant at Children's Hospital of Pittsburgh.

Others are finishing an M.S. degree in Colloids, Polymers and Surfaces at Carnegie Mellon University and working with CityYear through Americorps while applying to law school. Many are attending PhD programs in areas like biomaterials, nuclear engineering, polymer science and chemistry at top institutions including Stanford, UC Berkeley, Yale and the University of Illinois at Urbana Champaign. Chemistry majors often comment with enthusiasm regarding the close-knit community, which includes the opportunity to network with alumni through the Undergraduate Seminar program in chemistry.

Degree Pathways

The Department offers three Bachelor's degrees: the B.S. in Chemistry, The B.S. in Chemistry/Biological Chemistry Track and the B.A. in Chemistry. One third of the courses for the B.A. degree are free electives that may be taken in any of the departments of the University and therefore offers a high degree of flexibility. For the B.S. degrees, electives are often technical courses in chemistry or related fields of science, technology and engineering, such as biology, physics, mathematics, chemical, biomedical or materials science engineering or computer science, although they can be in other non-technical areas as well. It is possible to have all of the technical requirements completed after the junior year in the B.S.

and B.A. degree programs, allowing students the flexibility to combine electives in the senior year into a focused program of specialization or to allow for additional breadth in their undergraduate experience. Students interested in graduate studies in chemistry may enroll in graduate courses. Those desiring immediate job placement may be interested in one or more of the formal options that supplement the chemistry B.S. degree. These are described in detail later in this section of the catalog. Carnegie Mellon has one of the strongest polymer science programs in the world and the undergraduate polymer science, materials chemistry or colloids, polymers and sciences options offer training that is particularly valuable for an industrial career. The Computational Chemistry option provides students with expertise in scientific computing that is highly sought after by employers in the pharmaceutical industry. Throughout the curriculum the use of computational tools is emphasized and students have access to state-of-the-art instrumentation in their courses and through undergraduate research as described below.

The overlap between the fields of chemistry and biological sciences continues to grow, with increased emphasis on synthetic chemicals that are used as probes or reporters of biological function and diagnostic and/or therapeutic agents. In addition, the application of sophisticated spectroscopic, structural and scanning probe/force methods on scales as low as single molecules is driving innovation and education at the chemistry/biology interface. Based on these trends the department offers the B.S. in Chemistry/Biological Chemistry Track to better prepare students for advanced studies and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course in bioorganic chemistry allows students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences. Students who complete the track will have been exposed to the latest research accomplishments and unanswered questions in biological chemistry while also gaining experience in experimental methods unique to research at this interface.

Honors Programs with Strong Research Focus

An honors program is offered for highly motivated undergraduates. It is designed primarily for students who wish to undertake a strong research-intensive program of study in contemporary chemistry. The program B.S. in Chemistry with Departmental Honors requires the completion of at least one graduate level course in chemistry, a research project, and the writing and defense of a bachelor's level honors thesis. An advanced track leading to the B.S. in Chemistry with Departmental Honors together with a Master of Science degree in chemistry involves completion of five graduate level courses and a more extensive thesis research project. This degree path is especially attractive to students who plan to pursue an industrial career. With enough advanced placement credit or by carrying heavier than usual course loads, students can complete the Honors/M.S. degree program in 8 semesters, with research during one to two summers. The majority of openings in the chemical industry presently are at the Bachelors and Masters degree levels.

Additional majors (double majors) are available with nearly all other departments in the university provided the student can fit the required courses into the schedule. Generally, all the requirements for both departments must be met for an additional major (except for some courses with similar content). Programs are also available that lead to the degree B.S. in Chemistry with a minor in another discipline. Requirements for most minor programs are described by individual departments in this catalog. However, it is recommended that students who are interested in pursuing a minor as part of their degree consult with the department involved for the current requirements and further guidance about scheduling. Dual degree programs are available in which students receive two separate undergraduate degrees from two different departments in the University. These require students to complete at least 90 units of work per additional degree in addition to the units required for the first degree and the core curriculum from both colleges if the programs are in different units. Several five-year programs have been developed to allow a Carnegie Mellon undergraduate student to earn both a B.S. in Chemistry and a Master of Science degree in fields such as Health Care Policy and Management, Materials Science Engineering, Colloids, Polymers and Surfaces or Biomedical Engineering.

Study Abroad

Study abroad programs are available for chemistry majors and programs of one to two semesters can generally be accommodated without delaying time to graduation beyond 8 semesters. One example of a formal exchange program is spending two semesters at École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland. Students can also study at the Carnegie

Mellon campus in Qatar. Study abroad is encouraged by the chemistry department and can be arranged on an individual basis at universities throughout the world including Europe, Asia, Africa, New Zealand, and Australia during the academic year, the summer and winter or spring breaks. Students interested in study abroad should consult with their academic advisor and the MCS Study Abroad Advisor in the Office of International Education.

Undergraduate Research Opportunities

One of the most attractive features of the Department of Chemistry is the opportunity for students to interact with prominent research scientists in entry-level as well as advanced courses and in research. Undergraduate laboratory instruction takes place in a state-of-the-art facility located in Doherty Hall. Participation in undergraduate research is encouraged and qualified students may begin projects as early as their first year through research shadowing experiences. Chemistry majors interested in beginning research should consult with the Director of Undergraduate Studies to begin the process of identifying a research mentor. Approximately 90 to 98% of the graduating chemistry majors during the past ten years have taken part in research either for pay or for credit as part of their undergraduate training. Chemistry majors have been very successful in obtaining Small Undergraduate Research Grants (SURG) and Summer Undergraduate Research Fellowships (SURF) from the University to help support their research projects. Several students each summer obtain iSURF support, International Summer Undergraduate Research Fellowships, to work with research collaborators abroad.

Faculty in the Department of Chemistry are leading the way in the use of computer-controlled instrumentation for synthesis and analysis of chemical compounds. In addition to automated science capabilities in individual labs, our faculty are engaged in the design and construction of the very first Academic Cloud Lab (<https://cloudlab.cmu.edu/>) that will be housed at Carnegie Mellon University and is scheduled to open in the spring of 2023.

This facility will allow graduate and undergraduate researchers to design and run experiments remotely, with the work carried out by robots and trained technicians according to computer code written by the researchers. In addition to use in research, our faculty have developed experiments within existing courses and created stand-alone courses utilizing the Emerald Cloud Lab; this coursework will transition to the Carnegie Mellon facility once it is opened.

Program Outcomes

The faculty members of the Department of Chemistry have approved the following as a statement of our learning outcomes for recipients of an undergraduate degree in chemistry.

Upon graduation recipients of the BS or BA degree in Chemistry will:

Foundational knowledge/theory

- Have a firm foundation in the quantitative and computational thinking that underlies chemistry, including use of modern computational tools.
- Have a firm foundation in the theories and models that form the basis for reasoning about molecular systems.
- Understand how the different subdisciplines of chemistry relate to and complement one another.
- Be able to apply chemical reasoning across disciplines, such as biology, environmental science, materials science, nanotechnology, and engineering.

Practical/Experimental

- Understand that chemistry is fundamentally an experimental science, and be able to identify or create an appropriate model, formulate a hypothesis, choose an appropriate set of tools and techniques, and design an experiment that tests the hypothesis and analyze the results from that experiment drawing sound scientific conclusions from the results obtained.
- Be proficient in the use of both classical and modern tools for analysis of chemical systems.
- Be able to design and carry out synthesis of both organic and inorganic systems.
- Be able to use experience and knowledge gained through theoretical and practical design projects to conduct further research.
- Know and follow the proper procedures and regulations for safe handling and use of chemicals and chemical equipment.

Communication

- Be able to convey information, both orally and in writing, to a range of audience levels and for a variety of purposes.

- Understand how scientific information is shared between peers in modern science, including responsible conduct for acknowledging prior and current contributions.
- Be able to locate, identify, understand and critically evaluate the chemical literature.
- Develop the interpersonal skills to function cooperatively in a team setting.

Society and ethics

- Understand the opportunities and consequences of chemistry for the environment and society for both the short term and for long-term sustainability.
- Understand and apply ethics and values to all professional activities.

Professional development

- Develop an understanding of career opportunities both within and outside of chemistry, including through contacts with faculty, the career and professional development center and alumni.
- Be prepared to pursue a life and career that builds on their experiences at Carnegie Mellon to achieve their personal goals and to contribute positively to society.

B.S. in Chemistry (and requirements for additional major in chemistry)

The majority of undergraduate degrees awarded by the Department of Chemistry are Bachelor of Science degrees. This degree program provides the most appropriate preparation for further graduate study and for industrial positions in research and development or analytical chemistry. The curriculum provides a strong foundation in the fundamental areas of study in chemistry: organic, physical, inorganic and analytical chemistry, along with a rich set of research-focused, instrumentation intensive laboratory experiences aligned with those areas. Students interested in less technical areas of employment or graduate study in areas such as business, policy or law may find the Bachelor of Arts degree a more suitable alternative.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses, 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum in B.S. in Chemistry and Requirements for an Additional Major in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

| Technical Breadth Requirements | | Units |
|--------------------------------|--|-------|
| 33-121 | Physics I for Science Students | 12 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| 03-121 | Modern Biology | 9 |
| or 03-231 | Honors Biochemistry | |
| or 03-232 | Biochemistry I | |
| 15-110 | Principles of Computing - or other approved programming course | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 21-120 | Differential and Integral Calculus | 10 |

| | | |
|-----------|---|----|
| 21-122 | Integration and Approximation | 10 |
| or 21-124 | Calculus II for Biologists and Chemists | |

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category of at least 6 units, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability, 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html>) (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/>)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

| Fall | | Units |
|-----------|---|-----------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 21-120 | Differential and Integral Calculus | 10 |
| 33-121 | Physics I for Science Students | 12 |
| 76-101 | Interpretation and Argument | 9 |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| | | 50 |

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

| Spring | | Units |
|---|---------------------|-------|
| 09-106 | Modern Chemistry II | 10 |
| Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or 09-116 a course that will allow you to shadow upperclass mentors in undergraduate research in chemistry. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year. | | |

| | | |
|-----------|---|-----------|
| 21-122 | Integration and Approximation | 10 |
| or 21-124 | Calculus II for Biologists and Chemists | |
| 33-121 | Physics I for Science Students | 12 |
| or 03-121 | Modern Biology | |
| or 15-110 | Principles of Computing | |
| xx-xxx | Arts, Humanities and Social Sciences Course 1 | 9 |
| xx-xxx | Free Elective | 9.0 |
| | | 50 |

Sophomore Year

| Fall | | Units |
|--|--|-----------|
| 09-201 | Undergraduate Seminar I | 1 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| Course is a prerequisite for 09-331, normally taken in the spring of the junior year | | |
| xx-xxx | Arts, Humanities and Social Sciences Course 2 | 9 |
| | | 41 |
| Spring | | Units |
| 09-202 | Undergraduate Seminar II: Safety and Environmental Issues for Chemists | 1 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-348 | Inorganic Chemistry | 10 |
| (Students wishing to pursue careers in the health professions or are pursuing the Biological Chemistry Track may wish to take biochemistry, 03-232, and delay inorganic until the junior or senior year spring semester) | | |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx | Arts, Humanities and Social Sciences Course 3 | 9 |
| | | 43 |

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two; though you should be careful about moving too many courses to the senior year as that may create additional stress at a time when you are preparing to move forward from CMU. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

| Fall | | Units |
|--|--|-----------|
| 09-301 | Undergraduate Seminar III | 1 |
| 09-231 | Mathematical Methods for Chemists | 9 |
| Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year. | | |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses. | | |
| or 09-323 | Bioorganic Chemistry Laboratory | |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring). | | |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Arts, Humanities and Social Sciences Course 4 | 9 |
| | | 41 |
| Spring | | Units |
| 09-302 | Undergraduate Seminar IV | 1 |

| | | |
|--------|---|--------------|
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| 09-331 | Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| xx-xxx | Cultural/Global Understanding Requirement | 9 |
| xx-xxx | Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester.. | 6-9 |
| | | 46-49 |

Senior Year

| Fall | | Units |
|--------|---|-----------|
| 09-401 | Undergraduate Seminar V | 1 |
| 09-xxx | Chemistry Elective (see notes on electives) | 9 |
| 38-110 | ENGAGE in Service | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Free Electives | 30 |
| | | 44 |
| Spring | | Units |
| 09-402 | Undergraduate Seminar VI | 3 |
| 09-xxx | Chemistry Elective (see notes on electives) | 9 |
| xx-xxx | Free Electives | 27 |
| | | 39 |

Distribution of Units for B.S. in Chemistry and Requirements for An Additional Major in Chemistry

Minimum Total Chemistry Units 160; See distribution below

Required Chemistry Courses* Units

| | | |
|-----------|--|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 09-231 | Mathematical Methods for Chemists | 9 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| or 09-323 | Bioorganic Chemistry Laboratory | |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-xxx | Chemistry Seminars | 8 |
| 09-xxx | Chemistry Electives | 18 |

* These, plus 33-121 Physics I for Science Students and 33-122 Physics II for Biological Sciences & Chemistry Students, are the required courses for students earning an additional major in chemistry.

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216

Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degree and the additional major in chemistry that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

| Other Requirements | Units |
|--|-------|
| Biology (Modern Biology or Biochemistry) | 9 |
| Computer Science | 10 |
| Mathematics | 20 |
| Physics | 21 |
| Interpretation and Argument | 9 |
| Arts, Humanities and Social Sciences Courses | 36 |
| Cultural/Global Understanding | 9 |
| EUREKA! (First-year seminar) | 6 |
| Science and Society requirement | 6 |
| ENGAGE in Service | 1 |
| ENGAGE in Wellness Courses (three courses) | 3 |
| ENGAGE in the Arts | 2 |
| Computing @ Carnegie Mellon | 3 |
| Free Electives | 65 |
| Minimum number of units required for the degree: | 360 |

The above B.S. curriculum recommends a range of 41-50 units per semester to meet the minimum degree requirement of 360 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives

Chemistry Electives

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. (Note: 09-291 without the addendum cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.A. in Chemistry

The curriculum for the B.A. degree provides students with the opportunity to take a substantial number of elective and non-technical courses. Certain chemistry, math, and other technical courses required for the B.S. degree are replaced by free electives, making this degree an ideal choice for those who wish to earn an additional major with one of the departments in the College of Humanities and Social Sciences, College of Fine Arts, or with the Business Administration program, though this is not a requirement. It is also attractive for students wishing to pursue careers in dentistry or pharmacy, career paths that require a broader preparation at the undergraduate level and hence more coursework outside of chemistry. Students may earn one or more of the options as described for B.S. degree candidates, providing they complete the courses listed.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses:

| Technical Breadth Requirements | Units |
|--|-------|
| 33-121 Physics I for Science Students | 12 |
| 33-122 Physics II for Biological Sciences & Chemistry Students | 9 |
| 03-121 Modern Biology | 9 |
| or 03-231 Honors Biochemistry | |
| or 03-232 Biochemistry I | |
| 15-110 Principles of Computing | 10 |
| or 15-112 Fundamentals of Programming and Computer Science | |
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| or 21-124 Calculus II for Biologists and Chemists | |

Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective

are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (<https://www.cmu.edu/mcs/propel/requirements.html>) (<https://www.cmu.edu/mcs/propel/requirements.html>).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

First Year

| Fall | Units |
|---|-----------|
| 09-105 Introduction to Modern Chemistry I | 10 |
| or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications | |
| 21-120 Differential and Integral Calculus | 10 |
| 33-121 Physics I for Science Students | 12 |
| 76-101 Interpretation and Argument | 9 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 50 |

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

| Spring | Units |
|--|-----------|
| 09-106 Modern Chemistry II * | 10 |
| 21-122 Integration and Approximation | 10 |
| or 21-124 Calculus II for Biologists and Chemists | |
| 15-110 Principles of Computing | 10 |
| or 33-121 Physics I for Science Students | |
| or 03-121 Modern Biology | |
| xx-xxx Arts, Humanities and Social Sciences Course 1 | 9 |
| xx-xxx Free Elective | 9 |
| | 48 |

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

| Fall | Units |
|--|-----------|
| 09-201 Undergraduate Seminar I | 1 |
| 09-219 Modern Organic Chemistry | 10 |
| 09-221 Laboratory I: Introduction to Chemical Analysis | 12 |
| 33-122 Physics II for Biological Sciences & Chemistry Students | 9 |
| This course is required before graduation but need not be taken this semester. | |
| xx-xxx Arts, Humanities and Social Sciences Course 2 | 9 |
| | 41 |
| Spring | Units |
| 09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists | 1 |
| 09-220 Modern Organic Chemistry II | 10 |
| 09-222 Laboratory II: Organic Synthesis and Analysis | 12 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx Arts, Humanities and Social Sciences Course 3 | 9 |

| | | |
|--------|---------------|-----------|
| xx-xxx | Free Elective | 9 |
| | | 42 |

Junior Year

| | | Units |
|-----------|--|-----------|
| Fall | | |
| 09-301 | Undergraduate Seminar III | 1 |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| or 09-323 | Bioorganic Chemistry Laboratory | |
| 03-121 | Modern Biology | 9 |
| or 15-110 | Principles of Computing | |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Arts, Humanities and Social Sciences Course 4 | 9 |
| xx-xxx | Free Elective | 9 |
| | | 41 |

| | | Units |
|--------|--|--------------|
| Spring | | |
| 09-302 | Undergraduate Seminar IV | 1 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| xx-xxx | Cultural/Global Understanding Requirement | 9 |
| xx-xxx | Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester. | 6-9 |
| xx-xxx | Free Elective | 9 |
| | | 44-47 |

Senior Year

| | | Units |
|--------|-------------------------------------|-----------|
| Fall | | |
| 09-401 | Undergraduate Seminar V | 1 |
| 09-xxx | Chemistry Elective | 9 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| 38-110 | ENGAGE in Service | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| xx-xxx | Free Electives | 28 |
| | | 42 |

| | | Units |
|--------|--------------------------|-----------|
| Spring | | |
| 09-402 | Undergraduate Seminar VI | 3 |
| 09-xxx | Chemistry Elective | 9 |
| xx-xxx | Free Electives | 40 |
| | | 52 |

Distribution of Units

Minimum Total Chemistry Units 121; See distribution below:

| Required Chemistry Courses | | Units |
|----------------------------|---|-------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| or 09-323 | Bioorganic Chemistry Laboratory | |
| 09-xxx | Chemistry Seminars | 8 |
| 09-xxx | Chemistry Electives | 18 |

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics may be taken in lieu of 09-321 Laboratory III: Molecular Design and Synthesis or 09-323 Bioorganic Chemistry Laboratory. However the student must complete the necessary pre- and co-requisites of 09-231, 09-344, and 09-345. In this case 09-345 and 09-344 will count as chemistry electives towards the B.A. degree.

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course,

under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.A. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

| Other Requirements | Units |
|---|-------|
| Biology (either Modern Biology or Biochemistry) | 9 |
| Computer Science | 10 |
| Mathematics | 20 |
| Physics | 21 |
| Interpretation and Argument | 9 |
| Arts, Humanities and Social Sciences courses | 36 |
| Cultural/Global Understanding | 9 |
| EUREKA! (First year seminar) | 6 |
| Science and Society Elective | 6 |
| ENGAGE in Wellness (3 courses) | 3 |
| ENGAGE in Service | 1 |
| ENGAGE in the Arts | 2 |
| Computing @ Carnegie Mellon | 3 |
| Free Electives | 104 |
| Minimum number of units for the degree | 360 |

The above B.A. curriculum recommends a range of 40-50 units per semester. The total units actually taken may exceed the 360 unit minimum, but students are strongly encouraged to take the extra elective courses in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

Notes on Electives**Chemistry Electives**

A minimum of 18 units of chemical electives is required.

Chemical electives can be satisfied by 09-445 Undergraduate Research, or by most other chemistry courses 09-3xx or higher, undergraduate or graduate, for which the student has the necessary prerequisites, or by 03-231/03-232 Biochemistry I. Biochemistry also fulfills the Life Sciences requirement for the MCS technical breadth requirement. 09-435 Independent Study Chemistry, may only be used to fulfill this requirement with permission of the Director of Undergraduate Studies. Certain interdisciplinary courses (e.g. 39-xxx) relating to chemistry can also be used with permission by the Director of Undergraduate Studies. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. (Note: 09-291 without the addendum cannot count as a chemistry elective.) Only one of these two courses may be counted towards fulfillment of 18 units of chemistry electives.

The scheduling of these electives can vary and students should check with the department offering the course to see which courses are offered in any given year or semester and with the Director of Undergraduate Studies in the Department of Chemistry to ascertain whether the course is an acceptable chemistry elective.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education

and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

B.S. in Chemistry/Biological Chemistry Track

This degree is ideal for students who wish to better prepare themselves for advanced studies in biological chemistry or biomedical fields and a job market that values knowledge and skills from both disciplines. A combination of advanced research-focused lecture course offerings and a novel laboratory course modeling the drug discovery process will allow students to build the strong foundation typical of a successful chemistry major, while expanding out into applications of chemistry in the biological sciences.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses, 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

Curriculum

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors in the Biological Chemistry Track must at minimum take the following non-chemistry technical courses: Physics I for Science Students (33-121, 12 units), Physics II for Biological Sciences & Chemistry Students (33-122, 9 units), Modern Biology (03-121, 9 units), Principles of Computing (15-110, 10 units) (or other approved programming course), 21-120 Differential and Integral Calculus (10 units) and Integration and Approximation (21-122, 10 units) or Calculus II for Biologists and Chemists (21-124, 10 units). Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability, 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office ([https://www.cmu.edu/mcs/undergrad/advising/hss-](https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html)

[finearts/index.html](https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/) (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/>)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

| Fall | Units |
|--|-----------|
| 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications | 10 |
| 21-120 Differential and Integral Calculus | 10 |
| 33-121 Physics I for Science Students | 12 |
| 76-101 Interpretation and Argument | 9 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 50 |

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

| Spring | Units |
|--|-----------|
| 09-106 Modern Chemistry II * | 10 |
| 21-122 Integration and Approximation or 21-124 Calculus II for Biologists and Chemists | 10 |
| 03-121 Modern Biology or 33-121 Physics I for Science Students or 15-110 Principles of Computing | 9 |
| xx-xxx Arts, Humanities and Social Sciences Course 1 | 9 |
| xx-xxx Free Elective | 5 |
| | 43 |

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

| Fall | Units |
|--|-----------|
| 09-201 Undergraduate Seminar I | 1 |
| 09-219 Modern Organic Chemistry | 10 |
| 09-221 Laboratory I: Introduction to Chemical Analysis | 12 |
| 33-122 Physics II for Biological Sciences & Chemistry Students Course is a prerequisite for 09-331, normally taken in the spring of the junior year | 9 |
| 03-220 Genetics or other biological chemistry elective. | 9 |
| xx-xxx Arts, Humanities and Social Sciences Course 2 | 9 |
| | 50 |
| Spring | Units |
| 09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists | 1 |
| 09-220 Modern Organic Chemistry II | 10 |
| 09-222 Laboratory II: Organic Synthesis and Analysis | 12 |
| 03-232 Biochemistry I | 9 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |

| | | |
|--------|---|-----------|
| xx-xxx | Arts, Humanities and Social Sciences Course 3 | 9 |
| | | 42 |

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

| Fall | | Units |
|--------|--|-----------|
| 09-301 | Undergraduate Seminar III | 1 |
| 09-231 | Mathematical Methods for Chemists Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year. | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring). | 9 |
| 09-323 | Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses. | 12 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Arts, Humanities and Social Sciences Course 4 | 9 |
| | | 41 |

| Spring | | Units |
|--------|---|--------------|
| 09-302 | Undergraduate Seminar IV | 1 |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| 09-331 | Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| xx-xxx | Cultural/Global Understanding Requirement | 9 |
| xx-xxx | Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester. | 6-9 |
| | | 46-49 |

Senior Year

| Fall | | Units |
|-----------|--|-----------|
| 09-401 | Undergraduate Seminar V | 1 |
| 09-xxx | Biological Chemistry Elective 1 (see notes on electives) | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates 09-718::or 09-719 will also fulfill this requirement. | 9 |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| 38-110 | ENGAGE in Service | 1 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| xx-xxx | Free Electives | 21 |
| | | 44 |

| Spring | | Units |
|--------|---------------------------------|-------|
| 09-402 | Undergraduate Seminar VI | 3 |
| 09-348 | Inorganic Chemistry | 10 |
| xx-xxx | Biological Chemistry Elective 2 | 9 |
| xx-xxx | Biological Chemistry Elective 3 | 9 |

| | | |
|--------|----------------|-----------|
| xx-xxx | Free Electives | 18 |
| | | 49 |

Distribution of Units

Minimum Total Chemistry Units 187; See distribution below.

Required Chemistry Courses* Units

| | | |
|-----------|--|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 03-231 | Honors Biochemistry | 9 |
| or 03-232 | Biochemistry I | |
| 09-231 | Mathematical Methods for Chemists | 9 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | 9 |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-323 | Bioorganic Chemistry Laboratory | 12 |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-xxx | Chemistry Seminars | 8 |
| 09-xxx | Biological Chemistry Electives | 27 |

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the BS degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

| Other Requirements | Units |
|--|------------|
| Modern Biology | 9 |
| Computer Science | 10 |
| Mathematics | 20 |
| Physics | 21 |
| Interpretation and Argument | 9 |
| Arts, Humanities and Social Sciences courses | 36 |
| Cultural/Global Understanding | 9 |
| EUREKA! (First Year Seminar) | 6 |
| Science and Society Elective | 6 |
| ENGAGE in Wellness (3 courses) | 3 |
| ENGAGE in Service | 1 |
| ENGAGE in the Arts | 2 |
| Computing @ Carnegie Mellon | 3 |
| Free Electives | 38 |
| Minimum number of units required for the degree: | 360 |

The above B.S. curriculum recommends a range of 41-50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever

subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 360 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 370 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

| | | |
|-----------|---|----|
| 09-403 | Hooked: The Chemical Basis of Drug Addiction | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.) | 9 |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| 09-521 | Metals in Biology: Function and Reactivity | 6 |
| 09-522 | Kinetics and Mechanisms of Chemical and Enzymatic Reactions | 9 |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| 09-621 | Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623 | 6 |
| 09-623 | Future Lab- DNA Science in the Cloud | 6 |
| 09-737 | Medicinal Chemistry and Drug Development | 12 |
| 09-803 | Chemistry of Gene Expression | 12 |
| 03-220 | Genetics | 9 |
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| 03-320 | Cell Biology | 9 |
| 03-327 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 9 |
| 03-344 | Experimental Biochemistry | 12 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 03-390 | Molecular and Cellular Immunology | 9 |
| 03-391 | Microbiology | 9 |
| 03-435 | Cancer Biology | 9 |
| 03-439 | Introduction to Biophysics | 10 |
| 03-442 | Molecular Biology | 9 |
| 03-729 | Entrepreneurship and protein-based drug development | 6 |
| 03-871 | Structural Biophysics | 12 |
| 33-441 | Introduction to Biophysics | 10 |

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Options for the Bachelor's Degrees in Chemistry

The curriculum for the degree Bachelor of Science in Chemistry permits students to take a number of elective courses in chemistry and other fields, particularly in the junior and senior years. Students may wish to complete a group of elective courses from several specialty areas, called "options," to complement their technical education. Each option will complement the

Bachelor's degree in Chemistry and will provide students with expertise in a specific area not covered by the normal undergraduate curriculum. Options are noted on the student's transcript but not on the diploma.

For each of the following options, the student should refer to the previous description of the curriculum for the B.S. or B.A. degrees in chemistry. Required courses are unchanged, and the courses that should be taken as electives for each option are listed below. Chemistry courses within an option also count towards fulfillment of the chemistry elective requirement for the B.S. degree. The courses can fulfill MCS technical core requirements (and in some cases non-technical core requirements i.e the management option) but there is very limited ability to count a course for an option and also for a minor or additional major/degree in a related area. You will need to consult with the appropriate advisors about double counting issues.

A student who completes the recommended courses for any of these options will receive a certificate from the Department of Chemistry at Commencement as formal evidence of the accomplishment and a notation of this will be made on the student's transcript.

| BIOCHEMISTRY OPTION | | Units |
|---|--|-------|
| 03-231/232 | Honors Biochemistry (or Biochemistry) | 9 |
| 09-518/718 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | 9 |
| or 09-718 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| or 09-719 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| xx-xxx | 2 Electives in Biochemistry | |
| Elective courses may be chosen from the following list. (Other courses listed as electives for the Biological Chemistry Track may be possible with permission.) | | |
| 03-344 | Experimental Biochemistry | 12 |
| 09-737 | Medicinal Chemistry and Drug Development | 12 |
| 09-803 | Chemistry of Gene Expression | 12 |
| 03-439 | Introduction to Biophysics | 10 |
| 09-519/719 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | 9 |
| or 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | |
| or 09-718 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates | |
| POLYMER SCIENCE OPTION | | Units |
| 09-502/741 | Organic Chemistry of Polymers | 9 |
| 09-760 | The Molecular Basis of Polymer Mechanics | 12 |
| Two Electives in Polymer Science | | 9 |
| Elective courses may be chosen from the following list | | |
| 09-445 | Undergraduate Research (in a polymer area as approved by the Director of Undergraduate Studies and generally part of a longer term project) | 9 |
| 09-509/715 | Physical Chemistry of Macromolecules | 9 |
| 09-736 | Transition Metal Catalysis for Organic and Polymer Synthesis | 12 |
| 27-477 | Introduction to Polymer Science and Engineering | 9 |
| Other upper level courses in chemistry, biomedical engineering, materials science engineering or the colloids, polymers and surfaces program may be used with permission of the Director of Undergraduate Studies | | |
| MATERIALS CHEMISTRY OPTION | | Units |
| 27-100 | Engineering the Materials of the Future | 12 |
| 27-201 | Structure of Materials | 9 |
| Two Elective Courses of at least 9 units each from the list below | | |
| 27-202 | Defects in Materials | 9 |
| 09-445 | Undergraduate Research (in a materials area as approved by the Director of Undergraduate Studies and generally part of a longer term project) | 9 |
| 09-502/741 | Organic Chemistry of Polymers | 9 |
| 09-507/707 | Nanoparticles | 9 |
| 09-509/715 | Physical Chemistry of Macromolecules | 9 |
| 09-723 | Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology | 12 |
| 27-xxx | MSE course approved by Director of Undergraduate Studies | |

| ENVIRONMENTAL CHEMISTRY OPTION | | Units |
|--|--|-------|
| 09-510/710 | Chemistry and Sustainability 09-291::must be taken with 09-381 in order to count towards this requirement. | 9 |
| or 09-291 | Environmental Systems on a Changing Planet | |
| 09-524 | Environmental Chemistry | 9 |
| Two elective courses of at least 9 units each from the list below | | |
| 09-445 | Undergraduate Research 9 units of 09-445 can count towards this option if part of a longer term immersion and approved by the Director of Undergraduate Studies | Var. |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 09-529/729 | Introduction to Sustainable Energy Science | 9 |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| or 09-738 | Exposure and Risk Assessment for Environmental Pollutants | |
| 19-440 | Combustion and Air Pollution Control | 9 |
| 12-651 | Air Quality Engineering | 9 |
| 12-657 | Water Resource Systems Engineering | 9 |
| 12-702 | Fundamentals of Water Quality Engineering | 12 |
| MANAGEMENT OPTION | | Units |
| 70-100 | Global Business Global Business is intended for first-year and sophomore students only. Juniors and seniors interested in pursuing the management option must replace the course with a constrained elective as defined for the Minor in Business Administration. | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 70-122 | Introduction to Accounting | 9 |
| Tepper Constrained Elective: As defined in the 2022-23 Undergraduate Catalog these must be one of the following courses: 70-311, 70-371, 70-381, or 70-391 | | 9 |
| COMPUTATIONAL CHEMISTRY OPTION | | Units |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| or 15-150 | Principles of Functional Programming | |
| 21-127 | Concepts of Mathematics | 12 |
| 09-563/763 | Molecular Modeling and Computational Chemistry | 9 |
| xx-xxx | One Upper Level Computational Elective Course of at least 9 units from the list below | |
| 09-621 | Welcome to the Future Lab - Science in the Cloud Must be taken with 09-623 | 6 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-214 | Principles of Software Construction: Objects, Design, and Concurrency | 12 |
| 33-241 | Introduction to Computational Physics | 9 |

B.S. in Chemistry with Departmental Honors

Outstanding students with an interest in research are encouraged to consider the Honors program by the beginning of the junior year. The program combines a slightly modified B.S. curriculum with close faculty-student contact in an individual research project, concluding with the student's presentation and defense of a Bachelor's degree honors thesis to a Thesis Committee.

The B.S. in Chemistry with Departmental Honors curriculum follows the general sequence of courses that is listed for the B.S. degree. The honors program specifies that one of the two **chemistry** electives be a 12-unit graduate course, numbered 09-7xx or higher, and that of the remaining free electives required to reach the minimum 360 units for the degree, at least two be undergraduate research (totaling at least 18 units) and one be 09-455 Honors Thesis (taken for 6 units). Students will be encouraged to do more than the minimum amount of research, so stipends from the research advisor or other sources such as a Summer Undergraduate Research Fellowship are sometimes available for summer B.S. honors research.

By the end of the penultimate semester, candidates for the B.S. in chemistry may apply to be admitted for candidacy to the Honors B.S. program. Applications are available on the department Canvas site for chemistry majors. To be accepted, students will be expected to have shown excellent performance in class work - normally at least a 3.2 average QPA- and outstanding progress in undergraduate research. A statement of support from their research advisor is also required. Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The committee shall consist of at least one member of the Undergraduate Program Committee to be appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the proposed third member of their committee and confirm their participation.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

A written thesis suitable for an Honors B.S. degree is required and should be a clear exposition in proper scientific format of a research project done for at least 18 units of credit in 09-445 Undergraduate Research. The thesis should describe a substantive new contribution to a particular field of research. This could include, but is not limited to, the discovery of a new phenomenon, studies that enhance our understanding of a previously reported phenomenon, or the development of a new method or technique. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before it approves the Honors degree. The written thesis must be supplied to the members of the student's Thesis Committee no later than 1 week prior to the scheduled public defense. The defense is usually scheduled to take place during April or early May of the senior year (for a May graduation date but will change accordingly for an August or December graduation) and the Director of Undergraduate Studies will coordinate the selection of a suitable date. Students completing the B.S. with Departmental Honors in Chemistry will receive MCS College Honors as well.

The designations of MCS College Honors and Departmental Honors are noted on the transcript but not on the diploma. Only University Honors are noted on the diploma.

Honors B.S. - M.S. Program in Chemistry

Overview

Outstanding students seeking an advanced degree are encouraged to apply for admission to the B.S./M.S. Honors program as early as they can but only after having made some progress on a research project that could eventually be suitable for production of a Master's level thesis. Please note that this degree is available only with the B.S. in chemistry or the B.S. in Chemistry/Biological Chemistry Track and cannot be obtained by students pursuing a B.A. degree in chemistry. Typically, applications are submitted during the second half of the sophomore year but no later than the first semester of the junior year. (Later applications would only be considered in exceptional circumstances and would generally involve staying for a fifth year of study.) Participants will have the opportunity to earn in four years not only the degree B.S. in Chemistry with Departmental Honors, but also the degree Master of Science in Chemistry. This program is highly research intensive and is not appropriate for all students. Requirements include completing five graduate level courses as electives. (See notes on Honors B.S./M.S. electives.)

The schedule of courses for the B.S./M.S. program generally moves as many courses as possible forward in the curriculum, though this is not a requirement. This gives the student the following advantages: 1) greater perspective in selection of a research advisor, 2) greater maturity in performing independent research, and 3) the possibility of initiating the graduate course sequence in the junior year.

Application Process

A completed application, finished in collaboration with their thesis advisor, must be submitted to the Director of Undergraduate Studies who will then arrange for an application meeting with the student, research advisor and representatives of the department Undergraduate Program Committee. (The application is available on the Canvas site for undergraduate chemistry majors.) At this meeting the student is expected to give an oral presentation with visual aids that presents relevant background, a summary of work completed to date and a detailed plan for their thesis project including a projected timeline for completion of the thesis research and the thesis itself.

The presentation generally lasts around 15 minutes. The committee may have questions for the candidate and/or advisor.

Thesis Committee

Upon acceptance into the program, a Thesis Committee must be identified, which will monitor the progress of the student. The Director of Undergraduate Studies generally initiates this process. The committee shall consist of at least one member of the Undergraduate Program Committee appointed by the Director of Undergraduate Studies, the student's research advisor and a third faculty member agreed upon by the student and advisor. This third member can be from another department or institution and can be tenure track, teaching track or research track faculty. It is the student's responsibility to contact the third member of their committee, confirm their participation and notify the Director of Undergraduate Studies.

A Box folder will be created for each degree candidate. Information relevant to their candidacy that includes for example the completed application and written work products including documents and slides should be uploaded to this folder. The folder will be accessible to the student, members of the Undergraduate Program Committee and the student's thesis committee.

Research Engagement

The student is expected to keep the research advisor selected for the duration of the thesis project. Summer thesis research for 10 weeks in each summer following the sophomore and junior years is strongly suggested to assist the student in completing research of sufficient quantity and quality to complete their thesis. Students normally will be given stipends for their summer work either by their research advisor or by competing for a summer fellowship such as a Summer Undergraduate Research Fellowship available through the Undergraduate Research Office. A minimum of 30 units of 09-445 Undergraduate Research is required though this is rarely sufficient as the sole research experience. Participation in group seminars during the junior and senior years is expected. Students must present their research at least once at the Sigma Xi competition at Meeting of the Minds, the annual Carnegie Mellon undergraduate research symposium, typically at the end of the junior year. In addition, students must meet with their Thesis Committee at minimum each fall, though additional meetings may be required by the Thesis Committee, to update the committee on their progress and in the fall of the senior year must prepare a written summary of their research progress to date (5 pages) and their plans for the academic year (1 page). This report must state clearly what stage the work is in; it must be clear what work is complete and ready for publication.

Failure to maintain what the committee deems as suitable progress towards degree in either research or graduate coursework may result in release from the program. The final decision rests with the Director of Undergraduate Studies in consultation with the thesis committee.

A meeting with the thesis committee should occur during the first two weeks of the final semester. The purpose of this meeting is to determine whether the candidate has made sufficient progress in research to warrant the production of a suitably rigorous thesis towards an M.S. degree according to the planned upon schedule. If the student has not made appropriate progress, they may have the option of extending their time to degree or pursuing Departmental Honors through writing and defense of a senior honors thesis as described elsewhere in this catalog.

Preparation for Writing the Thesis and the Thesis Defense

By the end of the penultimate semester (normally fall of the senior year) the student should complete a thorough literature review to begin preparation for the introduction of their thesis.

At the start of the spring semester of the senior year (or their final semester if different), the student must submit a draft of the introduction for their thesis and a detailed outline of their methods, results and discussion sections to the Director of Undergraduate Studies who also chairs the Honors Committee. This will be distributed via Box and reviewed by the student's Thesis Committee.

Each student is required to submit a formal Masters Degree dissertation to the Chemistry Department in April of the senior year (for a May graduation date) or at least one week prior to the date set for the thesis defense. The thesis usually has an abstract, introduction, methods, results, discussion and conclusion sections with acknowledgements. It is common for a Masters dissertations to contain multiple chapters describing various aspects of the project. The student's Thesis Committee will evaluate the thesis via a public oral presentation followed by a private defense of the thesis before the Thesis Committee. The defense is usually scheduled to take place during April or early May of the senior year and the Director of Undergraduate Studies will coordinate the selection of a suitable date. The defense presentation generally lasts around 30-40 minutes.

The dissertation, written in proper scientific format, should describe the research project in considerable detail and must withstand the scrutiny of the Thesis Committee with respect to completeness. It need not be as extensive nor contain the element of student originality characteristic of a Ph.D. thesis; however it must contain results and conclusions that are

of a high enough quality to be accepted as a publication in a respected research journal, though publication of the work is not a requirement of the degree program. The student should refer to the ACS Style Guide for recommendations on appropriate presentation and formatting of written text, tables, graphs, and figures. As for all M.S. degree candidates in the Department, the dissertation must be approved first by the research advisor before it can be distributed to the rest of the committee. Thus, it is essential to give the complete thesis or individual chapters to the advisor for feedback well before the one-week deadline for submission to the full committee.

Research productivity is the most important criterion for success at the evaluation points, but QPA is a strong secondary criterion. A minimum of 3.2 and strong progress in research are required to remain in the program. Candidates must also maintain a QPA of at least 3.0 in the five graduate level courses required for the degree.

Students who complete this program will receive the designations of Departmental Honors and MCS College Honors. These are designated on the transcript, not on the diploma. Only University Honors are denoted on the diploma.

Students completing the requirements for this degree receive two diplomas, one for the B.S. degree and another for the M.S. degree. Since this is a combined degree program both degrees are awarded at the same time; the awarding of the two degrees cannot be separated in time. It is not uncommon for students to extend their time to degree through the summer following their planned May graduation in order to finish writing and defense of their M.S. thesis. These students are able to walk with their graduating class in May, though they will not receive their diplomas until after their thesis defense and submission of their grade for 09-455.

Failure to make progress in research or coursework of sufficient quality and quantity in a timely fashion can result in a student being removed from this degree program (removal of the M.S. degree from their record).

The decision will be made by the thesis committee and the Director of Undergraduate Studies. Violations of professional ethical standards can also result in a student's removal from the B.S.-M.S. program. This will not interfere with the student earning a B.S. degree, the BS with the Biological Chemistry Track or the B.S. degree with Departmental Honors, provided the appropriate requirements are met.

Notes on Honors B.S. - M.S. Graduate Level Electives

The B.S. - M.S. Honors degree requires the completion of five graduate level courses. Graduate courses in chemistry are typically those numbered 09-7xx or 09-8xx. Some courses numbered 09-6xx are remedial graduate level courses and not acceptable towards the degree requirements as the content overlaps extensively with required chemistry courses at the undergraduate level (an example is 09-611 Chemical Thermodynamics). Others are part of established M.S. programs in the college and may be possible candidates for fulfillment of this requirement (examples being 09-615 Computational Modeling, Statistical Analysis and Machine Learning in Science and 09-621 Welcome to the Future Lab - Science in the Cloud that must be taken with 09-623 Future Lab - DNA Science in the Cloud). Graduate classes in chemistry are normally 12-unit courses (or two six unit minis numbered 09-7xx or 09-8xx counting as one graduate level course). However, in order not to penalize interdisciplinary studies which may be essential to a good thesis, up to three of the five required graduate chemistry courses may be at the advanced undergraduate level (the 9 unit 09-5xx versions), though the 09-7xx course is generally preferred as the additional 3-units of work often target work or skills important to graduate-level work. All advanced undergraduate level courses used to satisfy this requirement must be approved by the Director of Undergraduate Studies. Students must earn a grade of C or better in each of the five graduate or upper level undergraduate courses fulfilling the requirements for this degree and also in 09-455, Honors Thesis. In addition students must earn a minimum of a 3.0 average combined for the five graduate or upper level undergraduate courses, 09-445 Undergraduate Research and 09-455 Honors Thesis in order to fulfill their degree requirements.

Curriculum for Students Pursuing the Honors B.S. - M.S. in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses: 33-121 Physics I for Science Students, 33-122 Physics

II for Biological Sciences & Chemistry Students, either 03-121 Modern Biology or 03-231 Honors Biochemistry or 03-232 Biochemistry I, 15-110 Principles of Computing (or other approved programming course), 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation or 21-124 Calculus II for Biologists and Chemists. Students should complete this technical core as early as possible and preferably by the end of their fifth semester. AP credit cannot be used to fulfill the technical breadth requirements for the core though AP classes can be used to fulfill prerequisites for chemistry classes.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category, a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability, 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html> (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/>)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses, 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

| Fall | Units |
|--|-----------|
| 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications | 10 |
| 21-120 Differential and Integral Calculus | 10 |
| 33-121 Physics I for Science Students | 12 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 76-101 Interpretation and Argument | 9 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 50 |

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences and 09-115 Introduction to Undergraduate Research in Chemistry., which can serve as the prerequisite for the research shadowing

course 09-116 Undergraduate Research Shadowing in Chemistry in the spring semester. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

| Spring | Units |
|--|-----------|
| 09-106 Modern Chemistry II Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective or inquire with the Director of Undergraduate Studies about a suitable research placement. | 10 |
| 21-122 Integration and Approximation or 21-124 Calculus II for Biologists and Chemists | 10 |
| 15-110 Principles of Computing or 33-121 Physics I for Science Students or 03-121 Modern Biology | 10 |
| xx-xxx Arts, Humanities and Social Sciences Course 1 | 9 |
| xx-xxx Free Elective | 9 |
| | 48 |

Sophomore Year

| Fall | Units |
|--|-----------|
| 09-219 Modern Organic Chemistry | 10 |
| 09-221 Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-201 Undergraduate Seminar I | 1 |
| 33-122 Physics II for Biological Sciences & Chemistry Students This course is a prerequisite for 09-331, normally taken in the spring of the junior year. | 9 |
| 09-445 Undergraduate Research | 9 |
| xx-xxx Arts, Humanities and Social Sciences Course 2 | 9 |
| | 50 |

| Spring | Units |
|---|-----------|
| 09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists | 1 |
| 09-222 Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-220 Modern Organic Chemistry II | 10 |
| 09-348 Inorganic Chemistry | 10 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx Arts, Humanities and Social Sciences Course 3 | 9 |
| | 43 |

Summer

10 weeks Honors Research recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

| Fall | Units |
|--|-----------|
| 09-301 Undergraduate Seminar III | 1 |
| 09-231 Mathematical Methods for Chemists | 9 |
| 09-321 Laboratory III: Molecular Design and Synthesis or 09-323 Bioorganic Chemistry Laboratory | 12 |
| 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-445 Undergraduate Research | 9 |
| 38-330 ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx Arts, Humanities and Social Sciences Course 4 | 9 |
| | 50 |

| Spring | Units |
|---------------------------------|-------|
| 09-302 Undergraduate Seminar IV | 1 |

| | | |
|--------|--|-----|
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-445 | Undergraduate Research | 6 |
| 09-xxx | Graduate Chemistry Course 1 of 5 (see notes on Honors B.S. - M.S. electives in the generalized program description) | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| xx-xxx | Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester. | 6-9 |

52-55

Summer

10 weeks Honors Research recommended

Senior Year

| Fall | | Units |
|--------|-------------------------------------|-------|
| 09-401 | Undergraduate Seminar V | 1 |
| 09-445 | Undergraduate Research | 9 |
| 09-xxx | Graduate Chemistry Course 2 of 5 | 12 |
| 09-xxx | Graduate Chemistry Course 3 of 5 | 12 |
| xx-xxx | Cultural/Global Understanding | 9 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| 38-110 | ENGAGE in Service | 1 |

45

Spring

| | | Units |
|--------|----------------------------------|-------|
| 09-402 | Undergraduate Seminar VI | 3 |
| 09-455 | Honors Thesis | 15 |
| 09-xxx | Graduate Chemistry Course 4 of 5 | 9 |
| 09-xxx | Graduate Chemistry Course 5 of 5 | 9 |
| 38-220 | ENGAGE in the Arts | 2 |
| xx-xxx | Free Elective | 9 |

47**Distribution of Units**

Minimum Total Chemistry Units (238, See distribution below)

| Required Chemistry Courses | | Units |
|----------------------------|--|-------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 09-231 | Mathematical Methods for Chemists | 9 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-xxx | Chemistry Seminars | 8 |
| 09-445 | Undergraduate Research (in addition 2 summers recommended) | 30 |
| 09-xxx | Graduate chemistry courses (see Notes on B.S./M.S. Electives) | 51-60 |
| 09-455 | Honors Thesis | 15 |

Students who transfer into the department and have taken 09-217 Organic Chemistry I, and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. - M.S. degree that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

| Other Requirements | Units |
|---|-------|
| Biology | 9 |
| Computer Science | 10 |
| Mathematics | 20 |
| Physics | 21 |
| Interpretation and Argument | 9 |
| Arts, Humanities and Social Sciences courses | 36 |
| Cultural/Global Understanding | 9 |
| EUREKA! (first year seminar) | 6 |
| Science and Society Elective | 6 |
| ENGAGE in Wellness (3 courses) | 3 |
| ENGAGE in Service | 1 |
| ENGAGE in the Arts | 2 |
| Computing @ Carnegie Mellon | 3 |
| Free Electives | 6-15 |
| Minimum number of units required for degrees: | 388 |

The above B.S. curriculum recommends a range of 41-55 units per semester to meet the minimum degree requirement of 388 units. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education, StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Curriculum for Students Pursuing the B.S. in Chemistry/ Biological Chemistry Track-M.S. Degree in Chemistry

This catalog and the sample schedules presented are intended to be used by students in the first year class entering in the fall of 2023. Upperclass students should refer to the appropriate previous version of the catalog published during their first year for the requirements that are specific to them.

The technical breadth requirement of the MCS core curriculum requires a minimum of four technical courses outside of the student's primary major. Chemistry majors must at minimum take the following non-chemistry technical courses: 33-121 Physics I for Science Students, 33-122 Physics II for Biological Sciences & Chemistry Students, either 03-121 Modern Biology **or** 03-231 Honors Biochemistry **or** 03-232 Biochemistry I, 15-110 Principles of Computing (or other approved programming course), 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation **or** 21-124 Calculus II for Biologists and Chemists. Students should complete this technical core as early as possible and preferably by the end of their fifth semester.

The non-technical breadth requirements for MCS students includes Interpretation and Argument (76-101, 9 units), four courses with a minimum of 36 units from the arts, humanities or social sciences and a course of at least 9 units from an approved list in the category of Cultural/Global understanding, a course in the Science and Society category,

a total of five ENGAGE courses including three ENGAGE in Wellness courses, ENGAGE in Wellness: Looking Inward (38-230, 1 units), ENGAGE in Wellness: Looking Outward (38-330, 1 units) and ENGAGE in Wellness: Looking Forward (38-430, 1 units), as well as ENGAGE in Service (38-110, 1 units) and ENGAGE in the Arts (38-220, 2 units) plus EUREKA!: Discovery and Its Impact (38-101, 6 units) the MCS first-year seminar for a minimum of 72 units.

The Science and Society requirement as well as the ENGAGE courses must be finished **prior** to your final semester at CMU (no later than your penultimate semester). The Science and Society requirement can be fulfilled in numerous ways via MCS classes and other disciplinary courses that can also fulfill other requirements for your degree (but can NOT double count within the general education categories i.e. a course used to fulfill Science and Society cannot also fulfill your Cultural Analysis requirement or count towards your 36 units of non-technical electives). In the chemistry department courses currently approved to fulfill the Science and Society requirement that can also count as a chemistry elective are 09-510 Chemistry and Sustainability , 09-291 Environmental Systems on a Changing Planet with 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum and 09-403 Hooked: The Chemical Basis of Drug Addiction. A more expanded listing will be maintained by the MCS Dean's Office (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/index.html>) (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/>)).

For more information on allowed courses in the arts, humanities and social sciences and electives in the Cultural/Global Understanding category refer to the MCS section of this catalog.

The suggested curriculum recommends that the required technical courses be completed at the earliest opportunity, however students have considerable flexibility to postpone these courses in favor of electives, allowing compatibility with the programs of other departments. In designing such programs for a minor or additional major with chemistry, students should note that certain required chemistry courses only are offered in specific semesters, not both. These include the Fall-only courses , 09-219 Modern Organic Chemistry, 09-321 Laboratory III: Molecular Design and Synthesis and 09-323 Bioorganic Chemistry Laboratory and 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry as well as the Spring-only courses 09-331 Modern Analytical Instrumentation, 09-220 Modern Organic Chemistry II, 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry and 09-348 Inorganic Chemistry. Also, in some cases, a course that is normally scheduled for the fall may be changed to a spring course (or the inverse) due to a departmental curriculum change or faculty availability.

The following are only meant to represent sample schedules. Students should always consult with their academic advisor to discuss an individualized plan to meet their academic goals.

Freshman Year

| Fall | Units |
|---|-----------|
| 09-105 Introduction to Modern Chemistry I | 10 |
| or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications | |
| 21-120 Differential and Integral Calculus | 10 |
| 33-121 Physics I for Science Students | 12 |
| or 03-121 Modern Biology | |
| 76-101 Interpretation and Argument | 9 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 50 |

Students interested in majoring in chemistry who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an A grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

There are some elective laboratory courses offered for MCS students in the first year. These include 03-117 Frontiers, Analysis, and Discovery in Biological Sciences or 09-115 Introduction to Undergraduate Research in Chemistry. The maximum units allowed during the first semester is 54; therefore, students wishing to take a lab should take an alternate technical course to Physics I such as 15-110 or 03-121 so that their unit total is lower.

| Spring | Units |
|---|-------|
| 09-106 Modern Chemistry II * | 10 |
| 21-122 Integration and Approximation | 10 |
| or 21-124 Calculus II for Biologists and Chemists | |
| 03-121 Modern Biology | 9 |
| or 33-121 Physics I for Science Students | |

| | |
|--|-----------|
| or 15-110 Principles of Computing | |
| xx-xxx Arts, Humanities and Social Sciences Course 1 | 9 |
| xx-xxx Free Elective | 5 |
| | 43 |

* Chemistry majors who place out of 09-106 can take 09-348 Inorganic Chemistry, 09-510 Chemistry and Sustainability as a chemistry elective, or other courses yet to be announced. Chemistry majors who feel they are ready for an undergraduate research experience should meet with the Director of Undergraduate Studies. These opportunities are more prevalent in the summer after your first year or sophomore year.

Sophomore Year

| Fall | Units |
|--|--|
| 09-201 Undergraduate Seminar I | 1 |
| 09-219 Modern Organic Chemistry | 10 |
| 09-221 Laboratory I: Introduction to Chemical Analysis | 12 |
| 33-122 Physics II for Biological Sciences & Chemistry Students | 9 |
| | Course is a prerequisite for 09-331, normally taken in the spring of the junior year. This course can be delayed until a subsequent semester in order to better manage workload. |
| 03-220 Genetics or other biological chemistry elective. | 9 |
| xx-xxx Arts, Humanities and Social Sciences Course 2 | 9 |
| | 50 |

| Spring | Units |
|---|-----------|
| 09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists | 1 |
| 09-220 Modern Organic Chemistry II | 10 |
| 09-222 Laboratory II: Organic Synthesis and Analysis | 12 |
| 03-232 Biochemistry I | 9 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx Arts, Humanities and Social Sciences Course 3 | 9 |
| | 42 |

Summer Research: 10 weeks of summer research is recommended

Reminder about Flexible Scheduling: Student feedback indicates that the junior year BS schedule can feel quite intense as you move into the more mathematical and physical chemistry oriented curriculum, especially if you are also engaged in undergraduate research. Remember that the senior year in chemistry is essentially open for free electives. You may use this flexibility to spread out your junior year requirements over four semesters rather than two. You should consult with your academic advisor to explore alternative schedules if you are interested.

Junior Year

| Fall | Units |
|--|--|
| 09-301 Undergraduate Seminar III | 1 |
| 09-231 Mathematical Methods for Chemists | 9 |
| | Math methods is a co-requisite for 09-344 and a prerequisite for 09-345 (spring). If you move math methods to the fall of your senior year, you must also move 09-344, 09-345 and 09-322 to the senior year. |

| | | |
|--------|--|--------------|
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry Quantum is a prerequisite for Lab IV. If you move Quantum to the fall of the senior year, you must move Lab IV to the spring of the senior year. 09-344 is not a prerequisite for 09-345 (spring). | 9 |
| 09-323 | Bioorganic Chemistry Laboratory This lab class is not a prerequisite for 09-322; it can be moved to the fall of your senior year without impacting the spring junior year courses. | 12 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates One course from the set 09-518, 718, 519, 719 is required for the track. | 9 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Arts, Humanities and Social Sciences Course 4 | 9 |
| | | 50 |
| Spring | | Units |
| 09-302 | Undergraduate Seminar IV | 1 |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| 09-331 | Modern Analytical Instrumentation This course is a co-requisite of Lab IV. If you move it to the senior year, you must also move Lab IV. | 9 |
| xx-xxx | Cultural/Global Understanding Requirement | 9 |
| xx-xxx | Track Elective #2 (if you choose a class at the 09-5xx, 7xx or 8xx level it can double count for the track and the graduate classes for the MS degree.**) | |
| xx-xxx | Approved Science and Society elective. This course can be scheduled at any point during your studies but prior to your final semester. | 6-9 |
| | | 46-49 |

** Double counting: One of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree. This is reflected in the schedule below.

Summer Research: 10 weeks of summer research is recommended

Senior Year

| | | |
|--------|---|--------------|
| Fall | | Units |
| 09-401 | Undergraduate Seminar V | 1 |
| 09-xxx | Biological Chemistry Elective 3 (see notes on Biological Chemistry electives) | 9 |
| xx-xxx | Graduate Course 1 (see notes in general description of BS-MS degrees) | 9-12 |
| xx-xxx | Graduate Course 2 | 9-12 |
| 38-110 | ENGAGE in Service | 1 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| xx-xxx | Free Electives | 16-23 |
| | | 48-61 |

| | | |
|--------|--------------------------|--------------|
| Spring | | Units |
| 09-402 | Undergraduate Seminar VI | 3 |
| 09-348 | Inorganic Chemistry | 10 |
| xx-xxx | Graduate Course 3 | 9-12 |
| 09-455 | Honors Thesis | 15 |
| xx-xxx | Free Electives | 9 |
| | | 46-49 |

DISTRIBUTION OF UNITS

Minimum Total Chemistry Units 271; See distribution below

| | | |
|-----------------------------------|--|-------|
| Required Chemistry Courses* Units | | |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 03-231 | Honors Biochemistry | 9 |
| or 03-232 | Biochemistry I | |
| 09-231 | Mathematical Methods for Chemists | 9 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates either 09-718 or 09-719 can also fulfill this requirement | 9 |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-323 | Bioorganic Chemistry Laboratory | 12 |
| 09-322 | Laboratory IV: Molecular Spectroscopy and Dynamics | 12 |
| 09-xxx | Chemistry Seminars | 8 |
| 09-xxx | Biological Chemistry Electives | 27 |
| 09-445 | Undergraduate Research | 30 |
| 09-455 | Honors Thesis | 15 |
| 09-5xx/7xx | graduate classes for the MS (3-4 required depending upon double counting) | 27-48 |

Students who transfer into the department and have taken 09-217 Organic Chemistry I and/or 09-218 Organic Chemistry II, will be required to complete units of 09-435 Independent Study Chemistry, 1 unit per course, under the supervision of the instructor(s) for 09-219 and/or 09-220 in order to master the course content missed in this course sequence.

Students who transfer into the department and have taken 09-207 Techniques in Quantitative Analysis and/or 09-208 Techniques for Organic Synthesis and Analysis will be required to take a 3 unit transition course (09-215 Chemistry Tech I to Lab I Transition for 09-207 and/or 09-216 Chemistry Tech II to Lab II Transition for 09-208) to fulfill the major requirements for 09-221 and/or 09-222.

Chemistry courses required for the B.S. degrees that are numbered 09-2xx or higher must be taken at Carnegie Mellon University. Exceptions must be requested of and approved by the Director of Undergraduate Studies. In general such requests will be approved only under unusual or extenuating circumstances.

** Double counting: A maximum of one of the required bioorganic courses and an appropriate, upper level undergraduate or graduate level chemistry class can double count towards the three track electives and the five required graduate courses for the MS degree.

| Other Requirements | Units |
|-----------------------------|-------|
| Modern Biology | 9 |
| Computer Science | 10 |
| Mathematics | 20 |
| Physics | 21 |
| Interpretation and Argument | 9 |

| | |
|--|-----|
| Arts, Humanities and Social Sciences courses | 36 |
| Cultural/Global Understanding | 9 |
| EUREKA! (First Year Seminar) | 6 |
| Science and Society Elective | 6 |
| ENGAGE in Wellness (3 courses) | 3 |
| ENGAGE in Service | 1 |
| ENGAGE in the Arts | 2 |
| Computing @ Carnegie Mellon | 3 |
| Free Electives | 15 |
| Minimum number of units required for the degree: | 388 |

The above B.S. curriculum recommends a range of 41-50 units/semester to meet the minimum degree requirement. Students are strongly encouraged to take extra elective courses (except in the first year) in whatever subjects they wish in order to enrich their backgrounds and enhance their educational experience.

Some students may need to earn more than 388 units to complete their degree. Usually this happens when students earn AP Credit for a course (for example 09-105) and then take a class with the same or similar content (take 09-105 at CMU or 09-107). You cannot count 20 units towards a 10-unit requirement so this student would need to earn 398 total units.

NOTES ON ELECTIVES

Biological Chemistry Electives

A minimum of three biological chemistry electives for a total of 27 units or more is required.

A list of currently approved electives is provided below. Of the three elective courses at least two should be chemistry courses and a maximum of one can be taken in biology or physics. Exceptions can be granted by the Director of Undergraduate Studies. One semester of 09-445 for 9 units may be used for one biological chemistry elective with the approval of the Director of Undergraduate Studies. It must be part of a longer term experience ensuring depth of knowledge in the area.

| | | |
|-----------|---|----|
| 09-403 | Hooked: The Chemical Basis of Drug Addiction | 9 |
| 09-518 | Bioorganic Chemistry: Nucleic Acids and Carbohydrates (One of these two courses is required for the degree. The other can be used as a Biological Chemistry elective.) | 9 |
| or 09-519 | Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry | |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| or 09-738 | Exposure and Risk Assessment for Environmental Pollutants | |
| 09-521 | Metals in Biology: Function and Reactivity | 6 |
| 09-737 | Medicinal Chemistry and Drug Development | 12 |
| 09-803 | Chemistry of Gene Expression | 12 |
| 03-220 | Genetics | 9 |
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| 03-320 | Cell Biology | 9 |
| 03-327 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 9 |
| 03-344 | Experimental Biochemistry | 12 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-366 | Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 03-390 | Molecular and Cellular Immunology | 9 |
| 03-435 | Cancer Biology | 9 |
| 03-391 | Microbiology | 9 |
| 03-439 | Introduction to Biophysics | 10 |
| 03-442 | Molecular Biology | 9 |
| 03-729 | Entrepreneurship and protein-based drug development | 6 |
| 03-871 | Structural Biophysics | 12 |
| 33-441 | Introduction to Biophysics | 10 |

Free Electives

Free electives are defined as including any course offered by Carnegie Mellon except those in science or engineering fields that are primarily intended for non-majors. A maximum of 9 units total of Physical Education,

StuCo and/or ROTC courses combined can be counted as free elective units. The Chemistry Department does not require technical electives.

Minor in Chemistry

In order for a student to receive a minor in Chemistry in conjunction with a B.S. or B.A. degree from another (primary) department, the successful completion of six courses as distributed below is required. Students pursuing the minor must inform the Chemistry Department of their intentions in writing using the MCS form for declaration of a minor so that the minor designation can be approved prior to graduation. The form may be obtained from the MCS undergraduate webpage at www.cmu.edu/mcs/undergrad/advising/forms/. **It should be completed and submitted to the department office, DH 1317 (or keishawd@andrew.cmu.edu), no later than the end of the course add period of the final semester prior to graduation.** If you decide at a later date not to complete the minor, it would be helpful to notify the Director of Undergraduate Studies, ks01@andrew.cmu.edu, so that it can be removed from your record. Minors are listed on the transcript but not on the diploma.

Note: An introductory chemistry class equivalent to either 09-105 Introduction to Modern Chemistry I or 09-107 Honors Chemistry: Fundamentals, Concepts and Applications is a **presumed prerequisite** to beginning the minor in chemistry.

Course Requirements

A. Four Required Core Courses

| | | |
|-----------|---|------|
| 09-106 | Modern Chemistry II | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 9-12 |
| or 09-207 | Techniques in Quantitative Analysis | |
| 09-217 | Organic Chemistry I | 9-10 |
| or 09-219 | Modern Organic Chemistry | |

Choice of one of the following courses:

| | | |
|--------|--|----|
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-507 | Nanoparticles | 9 |
| 09-529 | Introduction to Sustainable Energy Science | 9 |

Courses in this group that are not used to satisfy Part A core courses may be used to satisfy elective course requirements in part B below, provided they are **not** required by the student's primary department. A single course cannot count as a requirement and one of two electives.

B. Two Elective Courses from the following list.

| | | |
|------------|---|------|
| 09-344 | Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 | Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 9-12 |
| or 09-208 | Techniques for Organic Synthesis and Analysis | |
| 09-218 | Organic Chemistry II | 9-10 |
| or 09-220 | Modern Organic Chemistry II | |
| 03-231/232 | Honors Biochemistry | 9 |
| 09-403 | Hooked: The Chemical Basis of Drug Addiction | 9 |
| 09-502 | Organic Chemistry of Polymers | 9 |
| 09-507 | Nanoparticles | 9 |
| 09-510 | Chemistry and Sustainability 09-291::must be taken with 09-381 in order to count as a chemistry elective. Chemistry electives are intended to enhance a student's technical knowledge in chemistry. Some chemistry courses are more interdisciplinary in nature and/or less technical in content. This applies to 09-510 Chemistry and Sustainability and 09-291 Environmental Systems on a Changing Planet plus 09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum. Only one of these two courses may be counted towards this requirement. | 9 |

| | | |
|-----------|---|----|
| or 09-291 | Environmental Systems on a Changing Planet | |
| 09-524 | Environmental Chemistry | 9 |
| 09-525 | Transition Metal Chemistry | 9 |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| 09-563 | Molecular Modeling and Computational Chemistry | 9 |
| 09-621 | Welcome to the Future Lab - Science in the Cloud must be taken with 09-623 | 6 |
| 09-714 | Advanced Organic Chemistry | 12 |
| 09-737 | Medicinal Chemistry and Drug Development | 12 |
| 09-760 | The Molecular Basis of Polymer Mechanics | 12 |
| 09-xxx | Approved Upper Level Chemistry Course (must be 09-3xx or higher but see exclusions noted below) | |

Courses in this section (part B above) can not be counted toward the minor if they are required **in any way** by the student's primary department or towards an additional major or minor other than as a free elective. For example, students majoring in Biological Sciences can not double count 03-231 (or 03-232), 09-208 (or 09-222), or 09-218 (or 09-220) toward the elective courses for the minor in chemistry. Chemical engineering majors can not count 03-231 (or 03-232) or a chemistry course that is used to satisfy that department's required chemistry or advanced chem/biochem elective.

09-231 Mathematical Methods for Chemists, does not count towards the minor in chemistry. The undergraduate research course 09-445 Undergraduate Research and 09-435 Independent Study Chemistry cannot be used for the minor.

Transfer credit will be accepted only for the prerequisite 09-105, or 09-106 and 09-217. All other classes towards the chemistry minor must be completed at Carnegie Mellon University.

Transfer Credit for Chemistry Courses

1. Requests for transfer credit for chemistry classes taken at other institutions should be made to Dr. Len Vuocolo, Associate Teaching Professor in the Department of Chemistry. Students making such requests should follow the policies and procedures in place within their home colleges in assembling materials for such requests. Consult with your advisor on the appropriate steps.
2. Requests should be placed **before** paying tuition for a class in case transfer credit is denied. Allow 1-2 weeks for approval.
3. At minimum requests must be accompanied by a complete syllabus including the textbook that will be used, a detailed list of topic areas and an indication of whether or not the course is part of the curriculum for science majors at the other institution. Check to ensure that the institution is on a semester system. Most schools on a quarter system (many in the UC system of schools) teach general chemistry and organic chemistry over three quarters each; therefore one of these classes would not be equivalent to one CMU class.
4. The department no longer accepts fully online courses.
5. No transfer credit will be awarded for the laboratory classes required for the chemistry or biology major at Carnegie Mellon University, 09-207, 09-221, 09-208, 09-222, 09-321, 09-323 and 09-322. Requests for transfer credit for 09-101, Introduction to Experimental Chemistry, will be accepted with the appropriate documentation.
6. In assessing the suitability of courses for transfer credit, the following factors are considered:
 - The rigor of the course must be comparable to that offered at Carnegie Mellon. This is usually assessed via the quality of the institution and its chemistry program, the textbook used and the amount of time spent on topic areas. In general, the rate of approval is significantly higher for four-year institutions with science majors as opposed to community colleges.
 - The topic areas should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University.
7. 09-105 Introduction to Modern Chemistry I focuses primarily on structure, bonding, interactions (and their influence on properties), and reactions (including quantitative relationships among substances in them). Detailed topics include the following:
 - Radiation and Its Interaction with Matter
 - Quantum Mechanics (wave-particle duality of matter, Heisenberg Uncertainty Principle)

- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund's Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- Lewis Structures (octet rule and exceptions; formal charge)
- Resonance Structures
- Molecular shapes (including deviations from ideal bond angles)
- Molecular Polarity (greenhouse gases as application)
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them (chromatography as application)
- Valence Bond (Localized Electron) and Molecular Orbital Theory
- Pi Molecular Orbitals (and energy diagrams) of Conjugated Organic Molecules
- Band Theory of Metals, Semiconductors, and Insulators
- Determining number of moles and chemical formulas
- Writing and balancing chemical equations (in particular completing combustion and double displacement reactions - including acid-base and precipitation reactions)
- Stoichiometry and thermochemical equations (heat evolved in combustion of fuels as application)
- Stoichiometry - limiting reactant and percentage yield
- Gases (mainly ideal) and stoichiometric applications involving them
- Phase transitions
- Solutions (determining concentrations, dilution problems, stoichiometric applications, application of solubility rules to determine if a precipitate forms)
- Acid-base reactions, titrations and other stoichiometric applications of acid-base reactions
- Oxidation Numbers, Redox Reactions/Titrations, and other stoichiometric applications of redox reactions

8. 09-106 Modern Chemistry II focuses primarily on thermodynamics, kinetics and equilibrium. Detailed topic areas include the following.

- Thermochemistry and Thermodynamics (First, Second, and Third Laws, with gas expansion/compression applications, including reversible, adiabatic processes)
- Internal energy, enthalpy, entropy, Gibbs Free energy, and determination of spontaneity
- Kinetics : Determination of rate, order, rate laws (including application of pseudo-rate laws, application of integrated rate law to determine order, relationship between time and amount in a reaction, and half-life)
- Reaction mechanisms - applying fast equilibrium and steady-state approximations to determine rate law consistent with mechanism
- Chemical Equilibrium : determination of Q and K expressions, determination of direction in which reaction proceeds to achieve equilibrium (using Q and Le Chatelier's principles, quantitative calculations to determine K or amounts at various stages, dependence of K on temperature, relationship between Gibbs Free energy, Q, and K)
- Acid-Base Equilibria: writing dissociation equilibrium reactions and acid-base "neutralization" reactions, autoionization of water (determination of pH and pOH, use of K_w), writing K_a and K_b expressions from dissociation equilibria, quantitative equilibrium calculations for weak acids and bases, titrations between strong species, strong-weak species, and weak-weak species, buffers (calculations of pH and amounts, including how to make a buffer), polyprotic species (quantitative applications and titrations), solubility and precipitation equilibria, determination of K_{sp} expressions and quantitative applications of those expressions, complex ion formation equilibria, emphasis is placed on equilibrium problems that involve multiple types of simultaneous equilibria
- Electrochemistry: Electrochemical cell notation and writing half-reactions from it, Faraday constant to connect number of moles of electrons / reaction amounts with current, connection of Gibbs Free Energy to cell voltage (potential) at equilibrium and non-equilibrium conditions, determination of K 's (acid-base, solubility constants) or amounts using Nernst equation in concentration cells (K for cell reaction)

9. 09-111 Nanolegos: Chemical Building Blocks takes an applications or systems approach to exploring current significant research and technology,

as well as to explaining phenomena and problems in the world around us. The major contexts and phenomena that it explore in applying and connecting chemical concepts are: (1) sustainable energy, (2) charge motion in materials, (3) natural versus engineered catalysts, (4) polymeric materials, and (5) reversible reactions in environmental and biological chemistry.

The chemical concepts used to promote an integrated understanding of the above applications and systems are:

- Radiation and Its Interaction with Matter
- Atomic Structure (Schrodinger Model, quantum numbers, interpretation of orbitals and their relative energies)
- Interpretation of Periodic Table, including the writing of electron configurations, Aufbau Principle, and Hund's Rule
- Periodic Table Trends in Elemental Properties
- Photoelectron Spectroscopy
- Bonding models and their explanation of properties (types of solids, bond polarity, bond energies, and bond lengths)
- molecular structures of organic and inorganic compounds
- Resonance Structures
- Molecular shapes
- Molecular Polarity
- Interparticle (intermolecular) forces and comparing or predicting relative physical properties from them
- Multiphase Reaction Stoichiometry (including limiting reactants and percent yield)
- Thermodynamics (First, Second, and Third Laws - applications more toward chemical reactions)
- Acid-Base Chemistry
- Kinetics (phenomenological and mechanistic)
- Electrochemistry (redox reactions; battery technology)
 - o Equilibrium

10. 09-101 Introduction to Experimental Chemistry is a seven week (mini) laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic and inorganic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, and transition metal coordination chemistry.

The chemical concepts applied or discovered in the course are:

- molecular polarity and interparticle (intermolecular) forces
- synthesis of substances (empirical formulas, stoichiometry, and percent yield),
- spectrophotometric analysis (dilution and Beer-Lambert Law)
- kinetics (integrated rate laws and Arrhenius equation)
- equilibrium (Law of Mass Action, LeChâtelier's Principle)
- acid-base equilibria
- redox reactions
- thermochemistry (enthalpy, thermochemical equations)
- coordination chemistry
- The Laboratory Skills/Techniques involved are:
 - safe lab practices, waste disposal, and chemical hygiene
 - data/observation recording in lab notebook
 - graphing, analyzing, and interpreting experimental data
 - use of top-loading balance
 - chromatography (paper or silica plate)
 - filtration (gravity and vacuum)
 - recrystallization of solids
 - titrations (redox and acid-base; use of pH meter)
 - making of and dilution of solutions (including quantitative transfer of solute)
 - use of volumetric pipet
 - use of spectrophotometer
 - developing experimental procedures

Academic Advising

"I really love how close-knit the Department becomes over the course of four years. We are a relatively small department, so we get to truly become a family by the end of our time here. I actually think that experiencing college during a pandemic has made us even closer. Everyone in the Department is so supportive of each other rather than being cutthroat, which I really loved. I also really loved getting to perform in Murder Mystery

for three years, because it really connected me with the students from the other years within the Department." ~ 2022 Chemistry B.S.

Building meaningful relationships related to your personal, academic and professional development should be a key component of your undergraduate experience. In the Department of Chemistry we believe that strong academic advising is key in facilitating this process. The Director of Undergraduate Studies is a Teaching Professor of Chemistry who acts as the academic advisor for all students with majors, additional majors and minors in chemistry. MCS students transition from their first year advisors in the Dean's Office to their department advisor once they declare their majors, generally in the spring of their first year.

In the Department of Chemistry we are committed to the MCS philosophy that holistic advising with attention to the development of the whole person in all dimensions is key to success at CMU. Your academic advisor is certainly available for the more transactional processes such as developing a course schedule that allows you to make appropriate progress towards your degree. However more importantly she is also available to both be a resource and to point you towards additional connections to enable success in all aspects of your experience. You are encouraged to connect with your advisor early and build this relationship through scheduled and impromptu visits and e-mail, social events throughout the year as well as in the classroom. You will engage with your advisor in classes and seminars throughout your time as a major, facilitating a strong working relationship that will promote discussions of your successes, challenges and areas related to your health and well-being.

"It was such a welcoming place. I never felt competition or animosity among students. Since it was so small, it felt close-knit and like the professors really knew you." ~ 2022 Chemistry B.S.

In the Department of Chemistry most students find additional faculty mentors in small, personalized classroom experiences but even more significantly through undergraduate research where participation generally exceeds 95% in any given graduating class.

Faculty

BRUCE A. ARMITAGE, Professor and Department Head of Chemistry, Co-Director Center for Nucleic Acids Science and Technology - Ph.D., University of Arizona; Carnegie Mellon, 1997-

STEFAN BERNHARD, Professor of Chemistry - Ph.D., University of Fribourg (Switzerland); Carnegie Mellon, 2009-

MARK E. BIER, Research Professor of Chemistry and Director of the Center for Molecular Analysis - Ph.D., Purdue University; Carnegie Mellon, 1996-

EMILE BOMINAAR, Associate Research Professor of Chemistry - Ph.D., University of Amsterdam (The Netherlands); Carnegie Mellon, 1994-

TERRENCE J. COLLINS, Teresa Heinz Professor in Green Chemistry and Director of the Institute for Green Science - Ph.D., University Auckland, (New Zealand); Carnegie Mellon, 1988-

SUBHA R. DAS, Associate Professor of Chemistry - Ph.D., Auburn University; Carnegie Mellon, 2006-

NEIL M. DONAHUE, Thomas Lord University Professor of Chemistry, Professor of Chemical Engineering and Engineering and Public Policy and Director of the Steinbrenner Institute for Environmental Education and Research - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000-

SIMON FAULKNER, Assistant Teaching Professor of Chemistry at Carnegie Mellon University- Qatar - Ph.D., University College London (United Kingdom); Carnegie Mellon, 2019-

ISSAAC GARCIA-BOSCH, Associate Professor of Chemistry - Ph.D., University of Girona, Catalonia (Spain); Carnegie Mellon, 2021-

ROBERTO GIL, Research Professor of Chemistry and Director of the NMR Facility - Ph.D., Córdoba National University (Argentina); Carnegie Mellon, 2002-

GABRIEL DOS PASSOS GOMES, Assistant Professor of Chemistry and Chemical Engineering - Ph.D., Florida State University; Carnegie Mellon, 2022-

YISONG (ALEX) GUO, Associate Professor of Chemistry - Ph.D., University of California at Davis; Carnegie Mellon, 2014-

MICHAEL P. HENDRICH, Professor of Chemistry - Ph.D., University of Illinois; Carnegie Mellon, 1994-

OLEXANDR ISAYEV, Associate Professor of Chemistry - Ph.D., Jackson State University; Carnegie Mellon, 2020-

RONGCHAO JIN, Professor of Chemistry - Ph.D., Northwestern University; Carnegie Mellon, 2006-

ANNA KIETRYS, Assistant Professor of Chemistry – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 2020–

HYUNG J. KIM, Professor of Chemistry – Ph.D., State University of New York at Stony Brook; Carnegie Mellon, 1992–

TOMASZ KOWALEWSKI, Professor of Chemistry – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 2000–

MARIA KURNIKOVA, Professor of Chemistry – Ph.D., University of Pittsburgh; Carnegie Mellon, 2003–

DANITH LY, Professor of Chemistry – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2001–

KRZYSZTOF MATYJASZEWSKI, J.C. Warner University Professor of Natural Sciences and Co-Director of the Center for Polymer-Based Protein Engineering and Director of the Center for Macromolecular Engineering – Ph.D., Polish Academy of Sciences (Poland); Carnegie Mellon, 1985–

CARRIE MCDONOUGH, Assistant Professor of Chemistry – Ph.D., University of Rhode Island; Carnegie Mellon, 2022–

NIMER MURSHID, Assistant Teaching Professor – Ph.D., University of Waterloo; Carnegie Mellon, 2023–

KEVIN NOONAN, Associate Professor of Chemistry – Ph.D., University of British Columbia (Canada); Carnegie Mellon, 2011–

LINDA A. PETEANU, Professor of Chemistry – Ph.D., University of Chicago; Carnegie Mellon, 1992–

GIZELLE SHERWOOD, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2009–

GLORIA SILVA, Associate Teaching Professor of Chemistry – Ph.D., Universidad Nacional de Córdoba (Argentina); Carnegie Mellon, 2002–

KAREN H. STUMP, Teaching Professor of Chemistry and Director of Undergraduate Studies and Laboratories – M.S., Carnegie Mellon University; Carnegie Mellon, 1983–

RYAN SULLIVAN, Professor of Chemistry and Mechanical Engineering and Associate Director of the Institute for Green Science – Ph.D., University of California at San Diego; Carnegie Mellon, 2012–

STEFANIE SYDLIK, Associate Professor of Chemistry – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2015–

LEONARD VUOCOLO, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2005–

NEWELL WASHBURN, Associate Professor of Chemistry and Biomedical Engineering – Ph.D., University of California, Berkeley; Carnegie Mellon, 2004–

DAVID YARON, Professor of Chemistry – Ph.D., Harvard University; Carnegie Mellon, 1992–

JOHN PETERSON MYERS, CEO and Chief Scientist of Environmental Health Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 2010–

JAMES PETERSON, Adjunct Associate Professor of Chemistry and Associate Professor of Environmental and Occupational Health at the University of Pittsburgh – Ph.D., University of Essex, UK; Carnegie Mellon, 2004–

Courtesy

MICHAEL BOCKSTALLER, Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Johannes Gutenberg University (Germany); Carnegie Mellon, 2005–

ANDREW GELLMAN, Lord Professor of Chemical Engineering and Co-Director W.E. Scott Institute for Energy Innovation – Ph.D., University of California, Berkeley; Carnegie Mellon, 1992–

NOA MAROM, Assistant Professor of Materials Science Engineering and Faculty of Chemistry – Ph.D., Weizmann Institute of Science (Israel); Carnegie Mellon, 2016–

GORDON RULE, Professor of Biological Sciences and Head of CMU Qatar Biological Sciences Program and Faculty of Chemistry – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1995–

ALAN J. RUSSELL, Highmark Distinguished Career Professor of Chemical Engineering and Director of Disruptive Health Technology Institute – Ph.D., Imperial College of London; Carnegie Mellon, 2012–

JAMES SCHNEIDER, Professor of Chemical Engineering and Faculty of Biomedical Engineering and Chemistry – Ph.D., University of Minnesota; Carnegie Mellon, 1999–

LYNN WALKER, Professor of Chemical Engineering and Faculty of Chemistry and Materials Science Engineering – Ph.D., University of Delaware; Carnegie Mellon, 1997–

JOHN L. WOOLFORD JR., Professor of Biological Sciences; Co-Director of Center for Nucleic Acids Science and Technology and Faculty of Chemistry – Ph.D., Duke University; Carnegie Mellon, 1979–

Emeriti

GUY C. BERRY, University Professor Emeritus of Chemistry and Polymer Science – Ph.D., University of Michigan; Carnegie Mellon, 1960–

JOSEF DADOK, Professor Emeritus of Chemical Instrumentation – Ph.D., Czechoslovak Academy of Sciences; Carnegie Mellon, 1967–

REA FREELAND – PhD, Carnegie Mellon University; Carnegie Mellon, 1993–

SUSAN T. GRAUL, Associate Teaching Professor Emerita of Chemistry – Ph.D., Purdue University; Carnegie Mellon, 1992–

PAUL J. KAROL, Professor Emeritus of Chemistry – Ph.D., Columbia University; Carnegie Mellon, 1969–

ECKARD MÜNCK, Professor Emeritus of Chemistry – Ph.D., Technical University of Darmstadt (Germany); Carnegie Mellon, 1990–

GARY D. PATTERSON, Professor Emeritus of Chemistry – Ph.D., Stanford University; Carnegie Mellon, 1984–

STUART W. STALEY, Professor Emeritus of Chemistry – Ph.D., Yale University; Carnegie Mellon, 1986–

Adjunct Faculty

BERNARD CRIMMINS, Adjunct Associate Professor of Chemistry and Associate Professor, Department of Civil Engineering, Clarkson University and President of Academic Environmental/Analytical Consulting Services (AEACS), LLC. – Ph.D., University of Maryland; Carnegie Mellon, 2018–

Department of Chemistry Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

09-052 Summer Internship

Summer: 3 units

The Department of Chemistry considers experiential learning opportunities important educational options for its undergraduate students. One such option is an internship, normally completed during the summer. Students do not need to officially register for an internship unless they want it listed on their official transcripts. The Director of Undergraduate Studies (or designee) will add the course to the student's schedule, and the student will be assessed tuition for 3 units. Upon completion of the internship, students must submit a 1-2 page report on their work experience to the Director of Undergraduate Studies (or other designated faculty member). Verification by the internship supervisor must be received prior to a grade being awarded. After the reports have been reviewed and approved, and verification received, a "P" grade will be assigned. Special permission of Instructor is required to register for this course.

09-101 Introduction to Experimental Chemistry

All Semesters: 3 units

This is a seven week chemistry laboratory course that is designed to introduce students to some basic laboratory skills, techniques, and equipment commonly used in experimental chemical investigations. The experiments will apply concepts in organic synthesis, quantitative analysis using visible spectrophotometry, kinetics, acid-base chemistry, thermochemistry, transition metal chemistry, and chromatography. 1 hr. lec., 3 hrs. lab.

09-103 Atoms, Molecules and Chemical Change

Fall: 9 units

Atoms, Molecules and Chemical Change is a self-contained one-semester introductory college chemistry course for students who have a high-school background in science and mathematics but who have decided not to major in a STEM field (science, technology, engineering, or mathematics). Students will develop fundamental chemical knowledge in topics such as stoichiometry, atomic theory, molecular bonding and structure, chemical reactions, thermodynamics, and electrochemistry. This knowledge will be applied to a variety of topics, including biological, industrial, environmental, agricultural, and culinary applications, helping students to understand how chemistry affects environmental, social, political, and economic issues. Through this course, students will develop both qualitative understanding and quantitative skills in chemistry. Students with credit for 09-105 or other more advanced chemistry courses are not permitted to enroll in this course. 3 hrs. lec., 1 hr. rec.

09-105 Introduction to Modern Chemistry I

Fall and Spring: 10 units

This course first investigates the establishment of some fundamental principles of chemistry and then progresses through the presentation of chemically interesting applications and sophisticated problems. It explores an understanding of matter and the energy changes associated with it, beginning with the atom. It then overviews how atoms interact and react to form the more complicated structures of molecules and ionic compounds. How the structure of elements and compounds affects their properties, function, and reactivity will then be explored. Finally, the quantification of the changes during the reactivity of substances through bond breaking and forming will be investigated in single and multiple phase reactions, such as acid-base and redox reactions. Topics will be presented to promote mastery of "depth over breadth of topics" and "conceptual understanding before using applicable equations". The course covers the major principles of atomic structure, chemical bonding, molecular structures of organic and inorganic compounds (including some transition metal complexes), interaction of substances, multiphase reaction stoichiometry, acid-base reactions, and redox reactions. Relevant examples will be drawn from such areas as environmental, materials, and biological chemistry.

09-106 Modern Chemistry II

Fall and Spring: 10 units

This course provides an overview of thermodynamics, kinetics and chemical equilibrium. Topics include the flow of energy in chemical systems; the spontaneity of chemical processes, i.e. entropy and free energy; the mechanisms and rates of chemical reactions; and the use of chemical equilibrium to reason about acid-base chemistry, solubility and electrochemistry. Applications include the energy economy, biological systems and environmental chemistry. 3 hrs. lec., 2 hrs. rec. Prerequisites: 09-105 or 09-107

09-107 Honors Chemistry: Fundamentals, Concepts and Applications

Fall: 10 units

This is an honors introductory course designed to provide students with a rigorous coverage of general chemistry in the context of grand challenges in the field. Traditional topics, such as equilibrium, kinetics, acid-base chemistry, and quantum chemistry, will be discussed through current research on nucleic acid-based therapeutics, atmospheric chemistry of pollutants, and catalysts for the production of solar fuels. The approach will integrate traditional lectures and readings from the textbook with discussions of journal articles, on-line content on research methods, and guest lectures from CMU faculty in these areas. This course assumes strong preparation in chemistry (AP Chemistry score of 3 or greater; IB Chemistry score of 5 or greater; SAT II Chemistry exam with a score of 700 or greater) and will be offered at an accelerated pace. The goal is to teach core principles of chemistry while exposing students to the diversity of modern chemical research and how it is addressing grand challenges facing society. 3 hrs. lec., 2 hrs. rec.

09-108 The Illusion and Magic of Food

Fall: 6 units

Have you ever wondered about your food? Why the freshly squeezed orange juice spoils after few hours while the one from the market lasts so much longer without apparent alteration? Why roasted food is so delicious? What is the nutritional value of milk and honey? Why soft drinks are damaging the teeth? What is the Impossible Burger? These and many more questions will be answered in this course, not only by the instructor but also through the student's research and curiosity. This course will introduce chemistry concepts on an as-needed basis, but it will remain at a simple level. We expect to help the student understand what food is made of, its nutritional value, how it is processed to offer longer shelf life, and how elaboration and preservation procedures may affect critical components. The topics will vary depending on the student's motivation in learning about different concepts related to the food industry, from processing to analysis, to packaging, and appearance. We plan to discuss interesting things in every class and finish the course with a broad knowledge of what is on our table and a better criteria to select our food. 3 hrs. lectures per week.

09-109 Kitchen Chemistry Sessions

Intermittent: 3 units

Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. For this course high school background in chemistry would help but nothing more advanced is required. Concepts will be discussed on a need to know basis. Students with stronger chemistry backgrounds should enroll in 09-209. 3 hrs. lec. and lab

09-110 The Design and Making of Skin and Hair Products

Spring: 3 units

This hands-on course targets students from across the CMU community who are interested in learning how chemistry applies to their everyday life. We will focus on students gaining knowledge of the chemical components in cosmetic products and on the methods for preparing them (from shampoos and conditioners to lotions, soaps, and creams). We will emphasize good laboratory practices and safety as well as the fundamental chemical and physical concepts that govern the product behavior and use. The overarching goal is that the students have a hands-on laboratory experience and develop a full understanding of the science behind the products that they use every day. No human or animal testing will take place as part of the curriculum.

09-111 Nanolegos: Chemical Building Blocks

Fall: 9 units

How does chemistry provide the foundation and building blocks in science, engineering, and technology? How does activity on the particle and molecular level that we cannot see cause things to happen and function on a level we CAN observe? What basic chemical concepts are needed as tools to understand current significant research and technology, as well as to understand phenomena and problems in the world around us? This course will emphasize answering these questions by presenting "problem- or context-first", then applicable chemical concepts on an as-needed basis. It is structured around phenomena relevant to modern society, research, and technology rather than the conceptual tools (i.e. systems- or application-, rather than content-driven). Many of the conceptual tools (e.g. structure, interaction between energy and matter, interparticle forces, reaction stoichiometry, thermodynamics and kinetics) are used throughout the course, to help reinforce these ideas and promote an integrated understanding. The major contexts and phenomena that we will explore in applying and connecting chemical concepts are: (1) sustainable energy, (2) charge motion in materials, (3) natural versus engineered catalysts, (4) polymeric materials, and (5) reversible reactions in environmental and biological chemistry

09-114 Basics of Food Science

All Semesters: 3 units

Food is essential for life and the maintenance of health. As consumers we know little about its constitution and processing. This course will shed light upon the main nutrients found in food and their properties. We will discuss the importance of different processing techniques and about the ingredients added to food that extend its shelf life, or that improve its mouthfeel, and appearance. Overall, this course aims to make students aware of the intrinsic value of food, and how its manipulation and eventual reconstitution leads to an acceptable final product found in the supermarket.

09-115 Introduction to Undergraduate Research in Chemistry

Fall: 2 units

Undergraduate research is an important activity in the training of undergraduate chemistry majors. This course is intended for students who are planning to declare a major in chemistry who are novices to research at the university level and have an interest in being better informed about strategies and skills that contribute to success. It is intended that this course will lead to an opportunity to participate in a series of shadowing opportunities through a second course in the spring semester where students will be mentored by upperclass students or PhD candidates in faculty laboratories. Spaces will be reserved for MCS students. Students from other colleges with a strong interest in a chemistry major or additional major should contact the Director of Undergraduate Studies in the Chemistry Department.

09-116 Undergraduate Research Shadowing in Chemistry

Spring: 2 units

This is a follow-up course to 09-115, Introduction to Undergraduate Research in Chemistry, which is intended to provide laboratory training for first-year MCS students who want to participate in research in chemistry as soon as their first year, but have not been through the teaching labs yet. Near the end of the fall mini for 09-115, students will be asked to rank their faculty/group interests for possible shadowing. Based on those rankings and faculty/mentor availability, in 09-116, students will be paired with mentors from research labs for seven-week shadowing experiences. Mentors may be graduate students or advanced undergraduate students carrying out research. At the beginning of each mini, the students and mentors will identify blocks of time each week for shadowing based on their schedules. If scheduling allows, students will also be encouraged to attend group meetings (this would count toward lab time). Shadowing will continue for seven weeks, at which time the students may rotate to a second group for another shadowing experience. We request a dedicated lecture room to ensure there is adequate space for the initial pairing and for an overview on assessments, and to allow for possible additional meetings as the course develops.

Prerequisite: 09-115 Min. grade C

09-122 Molecular Tools for Biological and Chemical Studies

Spring: 6 units

Fluorescent dyes are applied in numerous fields to aid in tasks such as mapping the course of water underground, examining the eye, and detecting biological events. This course is aimed at offering a hands-on laboratory experience in the interface of chemistry and biology, also known as bioorganic chemistry. In this lab students will learn about fluorescence and fluorescent compounds. They will prepare a dye and will measure its fluorescent properties in presence of different media. This behavior will be compared and contrasted with that of another dye that will be provided. A former student in the course says: "Molecular Tools for Biological and Chemical Studies was one of the highlights of my time at CMU! Taking this course during my freshman year allowed me to gain skill and confidence in the lab, and the concepts I learned helped me to excel in many other courses I took at CMU (including: Organic Chemistry I and II, Laboratory I: Introduction to Chemical Analysis, Laboratory II: Organic Synthesis and Analysis, Biochemistry, and Modern Analytical Instrumentation). Since graduating from CMU, I have been working on a Ph.D. in chemical biology. I still use many of the skills that I learned in Molecular Tools on a daily basis." Maddie Balzarini

09-201 Undergraduate Seminar I

Fall: 1 unit

Issues and topics of importance to beginning chemistry majors are discussed in this course. It provides a general introduction to the facilities, faculty and programs of the Department of Chemistry and introduces students to career and research opportunities in the field of chemistry. Enrollment limited to students majoring in chemistry. 1 hr.

09-202 Undergraduate Seminar II: Safety and Environmental Issues for Chemists

Spring: 1 unit

Issues and topics focused on laboratory safety are discussed in this class. The topics are selected to supplement information covered in 09-221, Laboratory I. This course is intended to provide the necessary safety training for students wishing to undertake undergraduate research projects in the laboratory and is taught in collaboration with the Office of Environmental Health and Safety. Enrollment is limited to chemistry majors. 1 hr.

09-204 Professional Communication Skills in Chemistry

Spring: 3 units

This required course for chemistry majors promotes development of written and oral communication skills in various formats within the discipline. Students are expected to develop these skills by becoming more familiar with the style and format of the chemical literature, current topics in chemistry, and research projects in the Department. Other learning outcomes include developing critical reading skills, providing effective feedback to peers' written and oral communication, demonstrating the ability to revise written work, and using chemical structure drawing software. 1 hr. lec.
Prerequisite: 09-221

09-207 Techniques in Quantitative Analysis

Fall: 9 units

09-207 is the first of two chemistry lab courses required for the BS and BA degrees in biological sciences and the intercollege major in biological sciences and psychology. It is also suitable for fulfilling the requirement for two general chemistry labs for admission to programs in the health professions. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. A mixture of individual and partner experiments are conducted during the semester. In addition to laboratory techniques, safety, and written communication skills are emphasized.

Prerequisites: 09-106 or 09-107 Min. grade A

09-208 Techniques for Organic Synthesis and Analysis

Intermittent: 9 units

09-208 is the second of two chemistry laboratory courses required for the BS in biological sciences and the intercollege major in psychology and biological sciences. It is also suitable for fulfilling the requirement for the laboratory experience for application to programs in the health professions. The course emphasizes experimental work in separations, synthesis, and analysis of organic compounds, including chromatography and spectroscopy. Written communication skills will be developed by means of laboratory reports and essays. 1 hr lec, 5 hrs lab

Prerequisites: (09-217 or 09-219) and (09-223 or 09-221 or 09-207)

09-209 Kitchen Chemistry Sessions

Intermittent: 3 units

Ever wanted to boil water in ice? Cook an egg so the yolk is set but the white still runny? Lick a lemon or drink vinegar but have it taste sweet? Make "caviar" from fruit juice and noodles from yogurt? Explore the science of molecular gastronomy through the lectures and demonstrations that reveal the chemistry and biochemistry of food ingredients and their preparation. Then use a kitchen as your "laboratory" to test hypotheses and delve into molecular cooking - you may just get to eat your lab results. Students enrolling in this course are assumed to have a college level background in chemistry including introductory organic chemistry. Students without a solid chemistry background should take the lower level 09-109. 3 hrs. lec. and lab

Prerequisites: 09-219 or 09-217

09-214 Physical Chemistry

Spring: 9 units

This is a one-semester course intended primarily for students majoring in Biological Sciences, students pursuing a B.A. degree program in Chemistry, and students in the B.S.A. program with a concentration in chemistry. The course focuses on thermodynamics, transport and reaction rates and their application to chemical and biological systems. Emphasis is given to attaining a good fundamental understanding of entropy and free energy. This is more a concepts than skills building course. Topics include applications of thermodynamics to chemical and biochemical equilibria, electrochemistry, solutions, and chemical kinetics. 3 hrs. lec.

Prerequisites: 09-106 and (21-122 or 21-124) and (33-106 or 33-111 or 33-121 or 33-141)

09-215 Chemistry Tech I to Lab I Transition

Fall and Spring: 3 units

09-215 is a 3-unit course intended for students who have taken 09-207, Techniques in Quantitative Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-221 Laboratory I: Introduction to Chemical Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-221 that are not introduced or are de-emphasized in 09-207. Students will also propose an idea for an independent lab-based project and carry it through all stages of development but not perform the actual lab work. The project development will require written work products as well as an oral presentation. The course must be completed before the last semester of the students degree program.

Prerequisite: 09-207 Min. grade C

09-216 Chemistry Tech II to Lab II Transition

Fall: 3 units

09-216 is a 3-unit course intended for students who have taken 09-208, Techniques in Organic Synthesis and Analysis, who decide later in their academic experience that they wish to pursue a degree or an additional major in chemistry. The chemistry major requires a 12-unit lab class, 09-222 Laboratory II: Organic Synthesis and Analysis. This course will utilize self-study and problem solving to introduce or reinforce key concepts covered in 09-222 that are not introduced or are de-emphasized in 09-208.

09-217 Organic Chemistry I

Fall: 9 units

This course presents an overview of structure and bonding as it pertains to organic molecules. Selected topics include: introduction to functional group chemistry, stereochemistry, conformational analysis, reaction mechanisms and use of retrosynthetic analysis in the development of multistep syntheses. Methods for structure determination of organic compounds by modern spectroscopic techniques are introduced. 3 hrs. lec., 1 hr. rec.

Prerequisites: 09-105 or 09-107

09-218 Organic Chemistry II

Spring: 9 units

This course further develops many of the concepts introduced in Organic Chemistry I, 09-217. Emphasis is placed on the utilization of reaction mechanisms for understanding the outcome of chemical transformations, and the employment of a wide variety of functional groups and reaction types in the synthesis of organic molecules. Also included in the course will be special topics selected from the following; polymers and advanced materials, biomolecules such as carbohydrates, proteins and nucleic acids, and drug design. 3 hrs. lec., 1 hr. rec.

Prerequisites: 09-217 or 09-219

09-219 Modern Organic Chemistry

Fall: 10 units

Traditional introductory organic chemistry courses present structure, reactivity, mechanisms and synthesis of organic compounds. Students taking 09-219 will be exposed to the same topics, but presented in greater depth and broader context, with applications to allied fields such as (1) polymer and materials science, (2) environmental science and (3) biological sciences and medicine. This will be accomplished through an extra 50 minute lecture period, where more advanced topics and applications will be discussed. Topics will include computational chemistry, green chemistry, chiral separations, photochemistry, reaction kinetics, controlled radical polymerizations and petroleum cracking. Students who complete 09-219 will have a strong foundation in organic chemistry as well as a sophisticated understanding of how organic chemistry is currently practiced. 4 hrs. lec., 1 hr. rec.

Prerequisites: 09-107 Min. grade A or 09-106

09-220 Modern Organic Chemistry II

Spring: 10 units

This course builds on 09-219 by introducing students to additional functional groups, chemical reaction mechanisms and synthetic strategies commonly used in the practice of organic chemistry. Advanced topics to be presented during the extra lecture will include multidimensional NMR spectroscopy, enantioselective synthesis, ionic polymerization, bioorganic and medicinal chemistry, natural products chemistry and toxicology. Students who complete 09-220 will have a strong foundation in synthetic, mechanistic and structural organic chemistry and will understand how this applies to human health and the environment. 4 hrs. lec, 1 hr. rec.

Prerequisite: 09-219

09-221 Laboratory I: Introduction to Chemical Analysis

Fall and Spring: 12 units

This course is the first in a sequence of four laboratory courses on experimental aspects of chemistry required for the B.S. and B.A. degrees in chemistry. The experimental work emphasizes the techniques of quantitative chemical analysis. Included are projects dealing with a variety of instrumental and wet chemical techniques. The course is project-oriented with the experiments becoming more complex, requiring greater student input into the experimental design as the semester progresses. A mixture of individual and team experiments are conducted during the semester. In addition to techniques, safety, written and oral communication skills, and effective teamwork are emphasized. 2 hrs. lec., 6 hrs. lab.

Prerequisites: 09-107 Min. grade A or 09-106

09-222 Laboratory II: Organic Synthesis and Analysis

Fall and Spring: 12 units

In this second course in the laboratory sequence, students acquire laboratory skills relevant to synthesis and purification of organic compounds, as well as the practical use of chromatography and spectroscopy. Students will also further develop technical writing skills through preparation of lab reports. 2 hrs. lec., 6 hrs. lab.

Prerequisites: (09-217 or 09-219) and (09-223 or 09-221)

09-224 Supramolecular Chemistry

Intermittent: 3 units

Supramolecular chemistry involves the use of noncovalent bonding interactions to assemble molecules into stable, well-defined structures. This course will provide students with an introduction to this exciting field of research, which is finding increasing applications in the biological and materials sciences, nanotechnology and medicine. Students will be introduced to essential background concepts such as types of noncovalent bonding and strategies for the design of supramolecular assemblies. Readings from monographs and classroom lectures by the instructor will cover this material. Students will then begin to read about applications of supramolecular chemistry from the scientific literature, learning to compare articles, to evaluate the quality of the data and interpretations reached by the authors, to use the knowledge gained from these readings and discussions to predict the outcomes of related experiments, and to ultimately be able to design their own experiments to answer research questions. Meeting hours set by instructor, enrollment limited with priority given to sophomore chemistry majors.

Prerequisites: 09-219 Min. grade C or 09-217 Min. grade C

09-225 Climate Change: Chemistry, Physics and Planetary Science

Fall: 9 units

Understanding the essential features of climate and climate change is a critical tool for modern citizens and modern scientists. In addition, the prevalence of climate skepticism in modern political discourse requires of citizens that they be able to think critically about a technical subject and also be able to distinguish reliable scientific experts from advocates. In this course we shall examine the climate of terrestrial planets (specifically Earth and Venus) through geological time and to the present, considering geochemical methods used to determine atmospheric composition over Earth's history (specifically the onset of oxygen in the atmosphere as well as the relationship between carbon dioxide and global temperature over geological timescales. The shorter climate history of Venus will be considered as a counter example, where the brightening dim young sun overwhelmed negative feedbacks in the weathering cycle, leading to a runaway greenhouse amplified by complete evaporation of the onetime Venus ocean. Throughout the course, we will consider climate change driven by human activity since the industrial revolution as a unifying theme.

Prerequisites: (09-105 or 09-107) and (33-121 or 33-151 or 33-141)

09-227 The Culture of Color: Dyes, Chemistry, and Sustainability

All Semesters: 9 units

One of the earliest forms of proto-chemistry, dyeing textiles has a long history of rich cultural traditions and technical innovations - which we will explore and practice. In this course students will focus on color through working with dyes for textiles scientifically, artistically, and culturally. You will learn the chemical science of color and techniques to isolate natural pigment for dyes as well as how to produce dyes synthetically. Students learn a variety of methods to apply our dyes to textiles to create beautiful patterns: immersion dyeing, resist and folding techniques, and printing. You will be exposed to the use of laboratory equipment and will be trained in good laboratory practices and safety. In preparation for your final project, throughout the course, we will discuss the cultural significance of colors, the origin of pigments, their production impact on the economy of the area, sustainability, and environmental impact of the waste produced by the textile dyeing industry.

Course Website: <http://www.chem.cmu.edu/>**09-231 Mathematical Methods for Chemists**

Fall: 9 units

This course uses mathematical approaches to develop models for chemical systems and materials from the bottom up, i.e. from atoms and molecules to substances. This course focuses on statistical mechanics and does not cover quantum mechanics basics. Math will be covered in the context of chemical phenomena, and combine topics from probability theory and statistics, 3-dimensional calculus, differential equations, and linear algebra. 3 hrs. lec.

Prerequisites: (09-107 Min. grade A or 09-106) and (21-124 or 21-122)

09-291 Environmental Systems on a Changing Planet

Fall: 9 units

This course introduces the interconnected environmental systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. These systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. We will explore how solar and biochemical energy moves through the Earth's interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with these systems. Case studies include the interplay between climate change feedbacks, wildfires, and forest ecosystems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the relevant information literacy required to understand current issues that are frequently debated in the public sphere, and connect these to environmental justice. This course draws on principles learned in high school science and serves as the foundational Earth and Environmental Science requirement for both the Minor and Additional Major in Environmental and Sustainability Studies. 09-291 is intended for both non-STEM majors from any program as well as STEM majors from any program in CIT, MCS, and SCS. In addition, STEM majors are strongly encouraged to take the connected 09-381 3-unit course that provides a more technical and quantitative framework for understanding the course content. 24-381 is often required for this course to count as a technical elective for STEM programs, and is required for students from CIT, MCS, and SCS in the Environmental and Sustainability Studies programs.

09-301 Undergraduate Seminar III

Fall: 1 unit

Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-302 Undergraduate Seminar IV

Spring: 1 unit

Students attend seminars presented by senior chemistry majors. Students provide peer evaluations of the seminars and through the process students become familiar with special topics in chemistry. The course establishes what should be included in a good seminar. This seminar course is one of 6 required for the chemistry major. If a schedule conflict exists, students may, with permission of the instructor, attend other chemistry seminars or make other arrangements to fulfill the requirement. 1 hr.

09-303 Hooked: The Molecular Basis of Addiction

Fall: 6 units

What makes us need something so much that it eclipses the most important aspects of our lives, such as family, friends, work, hobbies, health and wellness? There are many different types of addiction; this course will focus on molecular addictions, with an emphasis on those involving members of the opioid class of narcotics. The ongoing epidemic of opioid addiction, arising both from over-prescription of pain killers and recreational use of heroin, has been widely reported and continues to rise at alarming rates, ravaging our urban and rural communities. In this course, we will explore the complicated role of chemistry in this epidemic, including the good (elucidating mechanisms of action, developing clinically useful and safe opioids and non-opioids) and the bad (design and synthesis of increasingly addictive opioids). We will also discuss ethical questions faced by the pharmaceutical industry that develops, markets and sells these drugs, the medical community that prescribes them, the government agencies charged with regulating these activities and law enforcement agencies that attempt to stop the flow of drugs into and within the United States. The second half of the semester will focus on addiction to other drugs, including cocaine, marijuana, amphetamines, alcohol and nicotine. We will also discuss chemical approaches to treating addiction. Students who complete this course will emerge with a broad understanding and perspective on an issue that is of great scientific and societal importance. The course will be organized in units that begin with a historical/societal "big picture" overview, followed by technical discussions of the underlying chemistry and biochemistry, concluding with consideration of the societal implications of addiction to each particular substance.

09-321 Laboratory III: Molecular Design and Synthesis

Fall: 12 units

In this third course in the laboratory sequence, students will learn a variety of more advanced techniques for organic synthesis and characterization, and will gain experience with developing and designing synthetic procedures. Student writing skills are further reinforced through preparation of detailed lab reports. 2 hrs. lec., 6 hrs. lab.

Prerequisites: (09-218 or 09-220) and 09-222

09-322 Laboratory IV: Molecular Spectroscopy and Dynamics

Spring: 12 units

This laboratory course is devoted to physical chemistry experiments, which involve the use of modern spectroscopic instrumentation to probe the optical and magnetic properties of molecules. The experiments include the use of high-resolution infrared, laser Raman, NMR, EPR, fluorescence, and UV-visible spectroscopies. Additional experiments demonstrate methods for measuring enzyme-catalyzed reaction rate constants, and the use of scanning probe microscopy for imaging and characterization of biological macromolecules. Throughout the course the students will learn how to use computer algebra packages for rigorous data analysis and modeling and will develop the skills in basic electronics, and vacuum techniques. 2 hrs. lec., 6 hrs. lab.

Prerequisites: (09-223 or 09-221) and 09-344

09-323 Bioorganic Chemistry Laboratory

12 units

Bioorganic chemistry is concerned with the action of synthesized compounds on biological systems. In order to maximize the likelihood of identifying a biologically active compound, synthetic libraries are often employed, requiring extensive familiarity with simple, efficient chemical coupling steps and protecting group chemistry. In this inquiry based laboratory course, using a process that mimics the current practice in drug discovery by pharmaceutical companies, students will rationally design a compound library in hopes of finding a compound active against a selected biological target, search for active compounds in the library, and then quantitatively characterize any identified compounds for activity. Working in small groups, students will develop proposals for and execute the target assay selected, the library synthesis, and the screening approach. Students will write reports summarizing the results in each phase of the course. Throughout the course, students will be introduced to concepts relevant to industrial scientific research, including regulatory compliance, quality control and assurance, and intellectual property.

Prerequisites: (09-220 or 09-218) and 09-222

09-325 Special Topics in Chemistry: Environmental Systems on a Changing Planet

All Semesters: 9 units

This course introduces the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life, including human societies. Environmental systems are the fascinating connections between the oceans, atmosphere, continents, ecosystems, and people that provide our planet with resources that all life depends on. Human activities disrupt these natural systems, posing critical threats to the sustainable functioning of environmental systems. The course will explore how solar and biochemical energy moves through the Earth's interconnected systems, recycling nutrients; how complex environmental systems function to produce critical resources such as food and water; and how human activities interfere with environmental systems. Case studies include the interplay between climate change feedbacks, wildfires, and forest ecosystems; the hazards that everyday chemical toxins pose to ecosystems and human health and reproduction; and growing threats to ecosystem health and biodiversity. We will also develop the environmental, scientific, and information literacy required to understand current environmental issues that are frequently debated in the public sphere. This course draws on principles learned in high school science and satisfies the science requirement for the interdisciplinary Minor in Environmental and Sustainability Studies.

09-331 Modern Analytical Instrumentation

Fall: 9 units

This course will cover all aspects of analytical instrumentation and its application to problems in materials, environmental, and biological chemistry. Topics covered will include mass spectrometry, optical spectroscopies and NMR. In addition, the course will emphasize how to select an analytical method appropriate to the problem at hand, how to optimize the signal to noise obtained by a measurement, and the quantitative analysis of experimental data. Some basic electronics will be covered as well. 3 hrs. lec.

Prerequisites: (09-223 or 09-221 or 09-207) and (33-141 or 33-121 or 33-151)

09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry

Fall: 9 units

We will connect your qualitative understanding of atoms and molecules to a more quantitative treatment, so that each of you can independently assess the extent to which chemistry is based on fundamental principles. To do this we must study the basic principles of quantum theory, because atoms and molecules are quantum particles. These principles influence every aspect of how you think of chemistry and the course will challenge you to think in different ways about the stuff around you. Throughout the course we shall apply quantum principles to develop an understanding of molecular and atomic spectroscopy, and a concurrent understanding of how spectroscopy can be used to learn about the microscopic properties of atoms and molecules. 3 hrs. lec., 1 hr. rec.

Prerequisites: (09-107 or 09-105) and (33-151 or 33-121 or 33-106 or 33-111 or 33-141)

09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry

Spring: 9 units

The measurement and theoretical descriptions of the equilibrium properties of chemical systems are presented. Chemical thermodynamics is introduced at the upper division level. The phases of matter are discussed. The quantitative treatment of mixtures is developed. The detailed description of chemical equilibrium is elaborated. The measurement and theoretical description of the nonequilibrium properties of chemical systems are presented. Elementary transport properties are introduced. The principles of classical chemical kinetics are developed in great detail. 3 hrs. lec., 1 hr. rec.

Prerequisites: (09-107 or 09-106) and (21-259 or 09-231)

09-348 Inorganic Chemistry

Spring: 10 units

The focus of this class is understanding the properties of the elements and of the inorganic compounds. The electronic structure of elements is discussed as the basis for the element's organization in the Periodic Table and for their properties. We will discuss atomic structure, and bonding of diatomic and polyatomic molecules using different models such as Lewis structures, VSEPR and Molecular Orbital Theory (including group theory and linear combination of atomic orbitals). We will study the structure, spectroscopy, and reactivity of coordination complexes and their application in bioinorganic and organometallic chemistry. 3 hrs. lec., 1 hr. rec.

Prerequisites: (09-105 or 09-107) and 21-120

09-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum

Fall: 3 units

This is 3-unit addendum to the co-requisite 09-291: Environmental Systems on a Changing Planet. These courses introduce the interconnected Earth systems that regulate our climate and ecosystems, providing the resources required to sustain all life and human societies. Please refer to the course description for 09-291 for more information. While 09-291 is designed to be accessible to students from all Colleges and majors, this addendum allows students to engage with the material with more technical depth and quantitative understanding of the function and feedbacks of complex environmental systems. The additional 3-units of 09-381 provides students with an additional weekly meeting time for further material development and discussion, and with additional assignments and exercises on top of 09-291. 09-381 is intended for students from STEM majors in CIT, MCS, and SCS, but can be taken by any student interested in exploring the environmental science topics with greater depth. Science and engineering fundamentals will be further developed and applied to develop the quantitative understanding of the function and feedbacks of complex environmental systems. A background in the natural sciences or engineering (such as introductory-level courses) is strongly recommended for students considering taking 09-381. When taken with 09-291, 09-381 will count as a technical elective for most programs in these STEM colleges, while 09-291 on its own is not considered a technical elective. 09-381 with 09-281 is the correct course for students whose home colleges are CIT, MCS, or SCS. 09-291 is the recommended course for students whose home colleges are CFA, DC, or TBS. 09-381 with 09-291 serve as the foundational Earth and amp; Environmental Science requirement for STEM majors for both the interdisciplinary Minor and Additional Major in Environmental and Sustainability Studies.

09-401 Undergraduate Seminar V

Fall: 1 unit

Students attend seminars on current topics in chemistry. Students are sent a menu of choices for each week of the semester and may select topics of interest. Enrollment is restricted to students majoring in chemistry. 1 hr.

09-402 Undergraduate Seminar VI

Fall and Spring: 3 units

Students enrolled in this course present a 20 - 30 minute oral report on a current topic in chemistry. This may be from the student's research work or a special chemistry topic of general interest. Presentations or papers prepared for other courses are not acceptable for this purpose. Thoroughness in the use of the chemical literature is emphasized. The use of presentation aids such as PowerPoint is required. Other students in the class submit written evaluations of the presentation. Talks are recorded for viewing by the student and instructor as a means of providing individualized feedback about presentation skills. A seminar presentation is required of all chemistry majors. No exceptions possible. Enrollment is limited to students majoring in chemistry. 1 hr.

09-403 Hooked: The Chemical Basis of Drug Addiction

Fall: 9 units

What makes us need something so much that it eclipses other important aspects of our lives, such as family, friends, work, hobbies, health and wellness? There are many different types of addiction; this course will focus on molecular addictions, specifically those involving members of the opiate class of narcotics. The ongoing epidemic of opiate addiction, arising both from over-prescription of pain killers and recreational use of heroin, has been widely reported and continues to rise at alarming rates, ravaging our urban and rural communities. In this course, we will explore the complicated role of chemistry in this epidemic, including the good (elucidating mechanisms of action, development of clinically useful and safe opiates and non-opiate pain killers) and the bad (design and synthesis of increasingly addictive opiates). We will also discuss ethical questions faced by the pharmaceutical industry that develops, markets and sells opiates, the medical community that prescribes opiates, and the government agencies charged with regulating these activities. Students who complete this course will emerge with a broad understanding and perspective on an issue that is of great scientific and societal importance. 3 hrs. lec.
Prerequisites: 09-220 or 09-218

09-425 Special Topics in Chemistry: Environmental Exposure and Risk Assessment

All Semesters: 9 units

Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposome concept, -omics-based research, and strategies for discovering novel harmful contaminants.
Prerequisites: (09-107 or 09-106) and (03-231 or 03-232 or 09-217 or 09-219)

09-435 Independent Study Chemistry

All Semesters

The course allows students to earn academic credit for concentrated study in a topic area developed in conjunction with and monitored by a faculty member in the Department of Chemistry. These topics are distinct from projects that would rise to the level of undergraduate research either because they are in unrelated areas distinct from the faculty member's research interests or may constitute the investigation and compilation of existing information from a variety of resources and may not be expected to result in the generation of new information as is a reasonable expected outcome in undergraduate research (likely is not publishable).

09-445 Undergraduate Research

Fall and Spring

Properly qualified students may undertake research projects under the direction of members of the faculty, normally 6 to 12 hrs/week. A written, detailed report describing the project and results is required. Course may be taken only with the consent of a faculty research advisor in chemistry or on occasion in another department provided that the project is chemical in nature and with permission of the Director of Undergraduate Studies. The number of units taken generally corresponds to the actual number of hours the student actually spends in the lab doing research during the week. Maximum number of units taken per semester is 18.

09-455 Honors Thesis

Fall and Spring

Students enrolled in the departmental honors program (B.S. with Departmental Honors or combined 4-year B.S./M.S. degree) are required to enroll in this course to complete the honors degree requirements. A thesis written in an acceptable style describing an original research project, and a successful oral defense of the thesis topic before a Thesis Committee are required. Limited to students accepted into the honors program. (B.S. Honors candidates normally enroll for 6 units; B.S./M.S. candidates enroll for 15 units.)

09-502 Organic Chemistry of Polymers

Spring: 9 units

A study of the synthesis and reactions of high polymers. Emphasis is on practical polymer preparation and on the fundamental kinetics and mechanisms of polymerization reactions. Topics include: relationship of synthesis and structure, step-growth polymerization, chain-growth polymerization via radical, ionic and coordination intermediates, copolymerization, discussions of specialty polymers and reactions of polymers. 09-509, Physical Chemistry of Macromolecules, is excellent preparation for this course but is not required. 3-6 hrs. lec. (Graduate Course: 12 units, 09-741)
Prerequisites: 09-218 or 09-220

09-507 Nanoparticles

Intermittent: 9 units

This course discusses the chemistry, physics, and biology aspects of several major types of nanoparticles, including metal, semiconductor, magnetic, carbon, and polymer nanostructures. For each type of nanoparticles, we select pedagogical examples (e.g. Au, Ag, CdSe, etc.) and introduce their synthetic methods, physical and chemical properties, self assembly, and various applications. Apart from the nanoparticle materials, other topics to be briefly covered include microscopy and spectroscopy techniques for nanoparticle characterization, and nanolithography techniques for fabricating nano-arrays. The course is primarily descriptive with a focus on understanding major concepts (such as plasmon, exciton, polaron, etc.). The lectures are power point presentation style with sufficient graphical materials to aid students to better understand the course materials. Overall, this course is intended to provide an introduction to the new frontiers of nanoscience and nanotechnology. Students will gain an understanding of the important concepts and research themes of nanoscience and nanotechnology, and develop their abilities to pursue highly disciplinary nanoscience research. The course should be of interest and accessible to advanced undergraduates and graduate students in fields of chemistry, materials science, and biology. 3 hrs. lec.

09-509 Physical Chemistry of Macromolecules

Fall: 9 units

This course develops fundamental principles of polymer science. Emphasis is placed on physio-chemical concepts associated with the macromolecular nature of polymeric materials. Engineering aspects of the physical, mechanical and chemical properties of these materials are discussed in relation to chain microstructure. Topics include an introduction to polymer science and a general discussion of commercially important polymers; molecular weight; condensation and addition synthesis mechanisms with emphasis on molecular weight distribution; solution thermodynamics and molecular conformation; rubber elasticity; and the rheological and mechanical properties of polymeric systems. (This course is also listed as 06-609. Graduate Course: 12 units, 09-715) 3 hrs. lec.
Prerequisites: 09-345 or 09-347

09-510 Chemistry and Sustainability

Spring: 9 units

This course aims to educate students in the foundations of systematic leadership for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. For scientists, effectiveness in solving the technical challenges and redirecting cultural behavior is the defining substance of sustainability leadership. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological dimension, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation stone of transformative sustainability leadership, to the Collins Sustainability Compass and Code of Sustainability Ethics and to the Rob and #233;rt/Broman Framework for Strategic Sustainable Development (FSSD) as powerful guiding tools. The Collins Bookcase of Green Science Challenges organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disruptors. Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants and endocrine disruptor (ED) science EDs represent the single greatest sustainability challenge of everyday chemicals. The graded substance will take the form of take-home work. Students will primarily read key books and articles and will summarize and personally evaluate the material in essay assignments. The course is intended for upper level undergraduates and graduates. There are no other prerequisites. The class is limited to 25 students. The assignments are common to both undergraduate and graduate classes offerings. (Graduate course 12 units 09-710) 3 hrs. lec.

Prerequisites: 09-105 or 09-107

09-517 Organotransition Metal Chemistry

Intermittent: 9 units

The first half of this course focuses on the fundamentals of structure and bonding in organotransition metal complexes and how the results can be used to explain, and predict, chemical reactivity. The latter half of the course covers applications, and more specifically, homogeneous catalysts for industrial processes and organic synthesis. (Graduate Course: 12 units, 09-717)

Prerequisite: 09-348

09-518 Bioorganic Chemistry: Nucleic Acids and Carbohydrates

Fall: 9 units

This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of nucleic acids and carbohydrates, and their applications in chemistry, biology and medicine. Later in the course, students will have the opportunity to explore cutting-edge research in this exciting new field that bridges chemistry with biology. Students will be required to keep abreast of the current literature. In addition to standard homework assignments and examinations, students will have the opportunity to work in teams to tackle contemporary problems at the forefront of chemistry and biology. The difference between the 09-518 (9-unit) and 09-718 (12-unit) is that the latter is a graduate level course. Students signed up for 09-718 will be required to turn in an original research proposal at the end of the course, in addition to all the other assignments. (Graduate Course: 12 units, 09-718) 3 hrs. lec.

Prerequisites: (03-151 or 03-121) and (09-218 or 09-220)

09-519 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry

Spring: 9 units

This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of peptides, proteins and small molecules. Basic concepts of bioorganic chemistry will be presented in the context of the current literature and students will have the opportunity to learn about the experimental methods used in various research labs. An introduction to combinatorial chemistry in the context of drug design and drug discovery will also be presented. Students will be required to keep abreast of the current literature. Homeworks and team projects will be assigned on a regular basis. The homework assignments will require data interpretation and experimental design; and team projects will give students the opportunity to work in teams to tackle contemporary problems at the interface of chemistry and biology. Students enrolled in the graduate level course (09-719) will be required to turn in an original research proposal at the end of the course, in addition to the homework assignments, midterm, and final exam that are required for the undergraduate course. (Graduate Course: 12 units 09-719) 3 hrs. lec.

Prerequisites: (03-121 or 03-151) and (09-218 or 09-220)

09-521 Metals in Biology: Function and Reactivity

Intermittent: 6 units

Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspired inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, M and #246;ssbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques. Prerequisites: (09-347 or 09-345 or 09-214 or 09-344) and 09-348

09-522 Kinetics and Mechanisms of Chemical and Enzymatic Reactions

Intermittent: 9 units

This is a practical course aimed at learning the major modern tools which are essential for investigation of mechanisms of homogeneous chemical and enzymatic reactions. Rules of formal chemical kinetics in solution are first considered followed by basic principles of kinetics of enzymatic processes including inhibition, which is a key factor in the up-to-date drug design. The relationships between electronic structures, catalytic properties, and reactivity of biologically relevant metal complexes will be provided. Electrochemical and redox features of metal complexes will be reviewed. The course includes such hot topics as Fenton chemistry, Marcus's electron transfer concept, catalysis by Collins' TAML activators of peroxides, specific and general acid/base, proximal and micellar catalysis. Mechanistic pathways of action of hydrolases, kinases, hydrogenases, oxidases, peroxidases, cytochrome P-450, and other metalloenzymes will be described. The course is supplied by the recently published text (A. D. Ryabov "Practical Kinetics and Mechanisms of Chemical and Enzymatic Reactions" Cambridge Scholars Publishing, Newcastle upon Tyne, NE6 2PA, UK) which includes all the above mentioned themes (Graduate course: 09-722, 12-units) 3 hrs. lec. Prerequisite: 09-348

09-524 Environmental Chemistry

Spring: 9 units

Environmental pollutants are common consequences of human activities. These chemicals have a wide range of deleterious effects on the environment and people. This course will introduce students to a range of major environmental pollutants, with a particular focus on persistent organic pollutants. We will use chemical principles including thermodynamics, kinetics, photochemistry, organic reaction mechanisms, and structure-activity relationships to understand the environmental fate of major classes of pollutants. The transport of chemicals through the environment and their partitioning between air, water, soil, and people will be described. The major environmental reaction pathways (oxidation, photolysis, hydrolysis, reduction, metabolism) of common pollutants will be explored. This will provide students with the necessary knowledge to predict the chemical fate of environmental pollutants, and improve their understanding of the environmental impacts of their everyday chemical use and exposure. Specific topics include water quality, photochemical smog, organic aerosols, atmospheric chemistry and global climate change, toxicity of pesticides, and heterogeneous and multiphase atmospheric chemistry. The 12-unit course is intended for graduate students that want to explore aspects of the course more deeply. This includes additional requirements including a final term paper and in-class presentation, and additional advanced questions on the homework assignments. Prerequisites: 09-219 or 09-217

09-525 Transition Metal Chemistry

Intermittent: 9 units

This class is focused understanding the structure, spectroscopy and reactivity of 3d metal complexes. Based on ligand field theory, we will analyze the electronic structure of these metal complexes and we will briefly describe the main spectroscopic techniques that will allow for studying this topic (X-ray diffraction analysis, UV-vis, EPR, NMR, EXAFS and Mossbauer). The main focus of the course will be on analyzing the reactivity of 3d metal complexes in the context of metalloenzymes and small-molecule bioinspired complexes. The natural and synthetic metal complexes involved in O₂ reduction, H₂O oxidation, N₂ reduction, H₂ formation and functionalization of organic molecules (e.g. hydroxylation of C-H bonds, dehydrogenation of alcohols, etc.), and the reaction pathways by which these important processes take place will be studied in detail.

(Graduate Course: 12 units, 09-725) 3 hrs. lec.

Prerequisite: 09-348

09-529 Introduction to Sustainable Energy Science

Fall: 9 units

This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO₂ reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/ storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.

Prerequisites: (09-105 or 09-107) and (33-151 or 33-121 or 33-141)

09-531 Polymer Science

Fall: 9 units

Polymer science is a vibrant multidisciplinary activity. It uses the methods of chemistry, physics, chemical engineering, materials science and biology to create a coherent picture of the macromolecular world. This course is a survey of this field of endeavor suitable for Senior chemistry majors, or other students with a desire for a broad knowledge of the science and engineering of polymers. It covers a thorough description of the field, the synthetic chemistry of macromolecules, the physical chemistry of macromolecules, and the principles of polymer engineering and processing.

Prerequisites: (09-219 or 09-217) and (09-214 or 09-345 or 09-347)

09-534 Environmental Chemistry

Spring: 9 units

Solar energy and electrical energy from renewable resources need to be stored to resolve intermittency issues. Energy can be stored through charge transfer, changes in chemical bonding, or in electric polarization. This course will introduce students to general aspects of energy-storage technologies using these strategies, integrating scientific and engineering perspectives to discuss thermodynamics, mechanisms of energy storage, and fundamental aspects of efficiency, capacity, and power delivery. Then we will explore current and experimental technologies, covering supercapacitors, batteries, and water-splitting catalysts. By the end of the course, students will be able to apply chemical principles to understand energy-storage technologies and gain knowledge of important classes of these systems. Students enrolled in 09-734 (rather than 09-534) will also be required to write a 15-page NSF style proposal. 3 hrs. lec.

Prerequisites: (09-219 or 09-217) and (33-341 or 27-215 or 24-324 or 09-347 or 09-345)

09-535 Applied topics in Macromolecular and Biophysical Techniques

Fall: 9 units

Applications of physical chemistry are widespread. Physical chemical principles are fundamental to the methods used to sequence human genome, obtain high resolution structures of proteins and complex nucleic acids e.g., ribosome, and further provides the framework to predict how molecules fold in 3-dimension, how the different domains interact (inter- and intra-molecular interactions) to perform biological functions. The principles that were discussed in theory in undergraduate physical chemistry classes, will be applied in order to understand the molecular structures and dynamics in nucleic acids and proteins, and to more advanced molecular motors. In the last decade major advances have been made through single-molecule studies that provide finer details of macromolecules in action. This course aims to teach and apply physical chemistry as related to biological problems.

Prerequisites: (09-345 or 09-347 or 09-214) and (03-121 or 03-232 or 03-231)

09-538 Exposure and Risk Assessment for Environmental Pollutants

All Semesters: 9 units

Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposure concept, -omics-based research, and strategies for discovering novel harmful contaminants.

Prerequisites: 09-106 or 09-105 or 09-107

09-560 Computational Chemistry

Fall: 12 units

Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.

Prerequisites: 09-344 or 09-347 or 09-214 or 09-345

09-561 Computational Chemistry

Spring: 9 units

Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.

09-563 Molecular Modeling and Computational Chemistry

Spring: 9 units

Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This course I can count towards coursework requirements for chemistry PhD candidates. 3 hrs. lec.

Prerequisites: 09-345 or 09-347 or 09-344 or 09-214

09-604 Introduction to Chemical Kinetics

Spring: 6 units

Empirical description of the time evolution of chemical reactions. Inductive derivation of kinetic rate laws from actual data. Deductive derivation of kinetic rate laws from proposed mechanisms. Gas phase reactions, catalyzed reactions, enzyme kinetics. Theories of kinetic rate constants for gas phase reactions: unimolecular and bimolecular. Theories of solution phase reactions. Absolute reactions rate theory. Diffusion controlled reactions. Kinetics in highly viscous media. Activation energy and entropy. Volume of activation.

09-611 Chemical Thermodynamics

Fall: 6 units

This course provides an introduction to the general formalism of macroscopic thermodynamics and its applications to chemical systems. The main topics to be covered include: entropy maximum postulate, internal energy minimum postulate, various equilibrium conditions including chemical equilibrium, Legendre transformation and free energies, thermochemistry, phase equilibria and solution systems. Prerequisites: 09-231 and 09-345

09-614 Spectroscopy

Intermittent: 6 units

This is a course exclusively in optical methods, both time resolved and steady state. In addition to methodology, spectral interpretation in terms of group theory will be discussed. The time-dependent formalism of quantum mechanics will also be introduced. Molecules in gas phase and condensed phase will be discussed. Frequent use will be made of the current literature. Background consisting of undergraduate physical chemistry is assumed. This course has a prerequisite 09-344, Quantum Chemistry or permission of the instructor.

09-615 Computational Modeling, Statistical Analysis and Machine Learning in Science

Fall: 12 units

The purpose of this course is to provide a practical introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to STEM students. The course begins by covering fundamental concepts in ML, data science, and modern statistics such as the bias-variance tradeoff, overfitting, regularization, and generalization, before moving on to more advanced topics in both supervised and unsupervised learning. Students will choose a large dataset from a selection of biology, chemistry, math, or physics datasets hosted by PSC and use this dataset throughout the MS program. The topics of the course are taught with students analyzing the chosen dataset. An intensive knowledge of Python or another computing language is not a pre-prerequisite since students will be given at first simple scripts that they work with and then expand upon. This course is required for students enrolled in the MS program in Data Analytics for Science.

Prerequisites: (09-344 or 09-231) and (15-110 or 15-112)

09-621 Welcome to the Future Lab - Science in the Cloud

Fall: 6 units

You can be at home or anywhere in the world and still run experiments in a lab. This course is to introduce and train students in the use of an automated and remote cloud lab facility. Operations in the cloud lab are conducted through a computer console and internet access that allows the user to program equipment, set up experiments and analyze data. In this course, students will learn the steps to use the Wolfram language/Mathematica based Cloud Lab Command Center interface to remotely interact with the facilities and laboratory instruments in the cloud lab. Following training exercises, students will be able to select the appropriate equipment and reagents to prepare samples and solutions for laboratory analyses and experiments. (No prior knowledge of Mathematica is required but basic programming skills are helpful)

09-623 Future Lab- DNA Science in the Cloud

Fall: 6 units

This course uses an automated and remote cloud lab facility and will involve learning the steps to handle, manipulate and quantitate solutions of DNA and nucleic acids. Students will set up experiments that automate the dispensing, analysis and purification of nucleic acids and use DNA for biophysical measurements. Students will learn to remotely operate, design and execute experiments on state-of-the-art instrumentation to analyze DNA sequence and structure. Besides learning how to remotely use equipment and instruments for synthesis and analyses by spectroscopy and spectrometry, students will also learn about nucleic acids as part of their experiments. (Prior training in the use of the cloud lab is required)

Prerequisite: 09-621 Min. grade C

09-701 Quantum Chemistry I

Fall: 12 units

The main topics to be covered will include exploration of the Schrodinger equation, operators, particle in the box, harmonic oscillator and hydrogen atom, tunneling, Stern-Gerlach experiment and quantum mechanical postulates, time-independent and time-dependent perturbation theory, matrix diagonalization. The student will learn to master the fundamental concepts and techniques of quantum mechanics. The parallel mini course Mathematical Analysis for Chemistry will provide the necessary mathematical background.

09-702 Statistical Mechanics and Dynamics

Intermittent: 12 units

This course will address the application of statistical mechanics to chemical systems. Topics to be discussed include the calculation of thermodynamic functions, phase transitions and chemical equilibrium, calculation of the transport properties of gases and liquids and the elementary theory of chemical kinetics.

Prerequisites: (09-344 or 09-611) and 09-231 and 09-701

09-705 Chemosensors and Biosensors

Intermittent: 12 units

Chemosensors and biosensors rely on "recognition" and "signaling" elements to transduce a molecular-scale binding event into an observable signal. Students in this course will be introduced to current research and technology for detecting chemical and biological analytes in a variety of contexts, including environmental testing, biological probing and medical diagnostics. Recognition elements ranging from small organic molecules to antibodies will be presented, while various detection modes, including fluorescence, gravimetric and colorimetric, that illustrate different signaling elements will be discussed and compared. Issues to be addressed include sensitivity, selectivity and efficiency. Each sensor will be analyzed in terms of the physical chemistry, organic chemistry and/or biochemistry underlying its function. This is a graduate level course that may also be appropriate for upper level undergraduates in chemistry and the biological sciences. The material in 09-518/09-519 or 09-718/09-719 would be appropriate background material for this course. 3 hrs. lec.

Prerequisites: (03-231 or 03-121 or 03-232) and (09-220 or 09-218)

09-707 Nanoparticles

Intermittent: 12 units

This course discusses the chemistry, physics, and biology aspects of several major types of nanoparticles, including metal, semiconductor, magnetic, carbon, and polymer nanostructures. For each type of nanoparticles, we select pedagogical examples (e.g. Au, Ag, CdSe, etc.) and introduce their synthetic methods, physical and chemical properties, self assembly, and various applications. Apart from the nanoparticle materials, other topics to be briefly covered include microscopy and spectroscopy techniques for nanoparticle characterization, and nanolithography techniques for fabricating nano-arrays. The course is primarily descriptive with a focus on understanding major concepts (such as plasmon, exciton, polaron, etc.). The lectures are power point presentation style with sufficient graphical materials to aid students to better understand the course materials. Overall, this course is intended to provide an introduction to the new frontiers of nanoscience and nanotechnology. Students will gain an understanding of the important concepts and research themes of nanoscience and nanotechnology, and develop their abilities to pursue highly disciplinary nanoscience research. 3 hrs. lec.

09-710 Chemistry and Sustainability

Spring: 12 units

This course aims to educate students in the foundations of systematic leadership through chemistry and more for building a sustainable world. Many sustainability challenges are associated with commercial chemicals and with operational modes of the chemical enterprise. The course aims to challenge students to analyze and understand the root causes of unsustainability, especially in the technological dimension, to imagine a more sustainable world and to begin to define personal leadership missions. Students will be introduced to sustainability ethics as the foundation of transformative sustainability leadership, to a sustainability compass, to a Code of Sustainability Ethics and to various other helpful conceptual material as tools for analyzing the reasons our civilization has been failing to address its own unsustainability. The Collins Bookcase of Green Science Challenges organizes the technical content. It systematizes the major chemical sustainability challenges of our time: clean synthesis, renewable feed-stocks, safe energy, elemental pollutants, persistent molecular toxicants and endocrine disrupting chemicals (EDCs). Focal areas will be the technical, toxicological and cultural histories of elemental and molecular pollutants with particular emphasis on EDCs. Students will experience Legacy Lectures from some of the world's leading endocrine disruption scientists. The graded substance will take the form of take-home work. Students will primarily watch classic movies and read key books and articles and will summarize and personally evaluate the material in essay assignments. The course is intended for upper-level undergraduates and graduates although it is open to all students. The class is limited to 30 students. The assignments are common to both undergraduate and graduate classes offerings and 09-710 students will engage in additional projects. 3 hrs. lec.

Prerequisites: 09-105 or 09-107

09-711 Physical Organic Chemistry

Fall: 12 units

This course introduces students to the study of structure and reactivity of organic compounds from a physical and theoretical standpoint. Students will learn the fundamentals of molecular orbital theory along with some practical applications to aromaticity and anti-aromaticity. Methods are described for the study of reaction mechanisms by means of physical methods such as kinetics, isotope effects, substituent effects, and solvent effects. Important reactive intermediates are described, along with detection methods. This course may be suitable for upper level undergraduates in chemistry with the appropriate background in organic chemistry and physical chemistry. 3 hrs. lec.

Prerequisites: (09-218 or 09-220) and (09-347 or 09-344)

09-714 Advanced Organic Chemistry

Spring: 12 units

This course will expose the students to modern methods of organic synthesis including insights into the basis and mechanisms of chemical reactions. Topics include but are not limited to: modern spectroscopic analysis and structure determination, synthetic methods, retrosynthesis, organic reaction mechanisms, and references to separation techniques and some analytical methods. Upon completion of the course students should be able to design reaction schemes using scientific literature sources, evaluate their suitability for use in the lab and develop an aptitude in identifying the use of modern reagents that are more efficient, specific, safer and environmentally friendly. It is assumed that at minimum students will have completed at least two semesters of undergraduate coursework in organic chemistry and suggested that they have completed 09-222 and 09-321, the organic laboratory courses. 3 hrs. lec.

Prerequisites: 09-220 or 09-218

09-715 Physical Chemistry of Macromolecules

All Semesters: 12 units

This course addresses the fundamentals of polymer science with the emphasis on physicochemical consequences of chain nature of macromolecules and on the behavior of polymers in condensed state (polymers as soft condensed matter). The topics to be covered include: chain structure and molecular weight; molecular weight distribution; step growth and addition polymerization mechanisms; chain conformation and behavior of polymers in solution; concentrated solutions and phase separation behavior; rubber elasticity; introduction to polymer viscoelasticity and rheology; mechanical behavior of polymers; glass transition and crystallization; multicomponent polymeric materials; liquid crystalline polymers; polymers at surfaces and interfaces; self-assembly and nanostructure formation in synthetic and biological systems; conducting and semiconducting polymers. Graduate students taking the course for 12 units will be required to write a term paper on a selected topic. 3 hrs. lec.

Prerequisites: 09-347 or 09-345

09-716 Bioactive Natural Products

Spring: 12 units

This course is aimed at students with an interest in natural products research. Natural products are used as active components in medicinal products, as model compounds for further development into medicinally active drugs, as ingredients in food and for flavor and fragrances, among other very useful and interesting applications. An overview of the structural variety and activity of natural products will be presented along with their isolation and structural determination. Overall, the course will offer an introduction to the work that is customary in natural product research. This course will cover: Strategies to select the plant or marine material for study; main groups of natural products derived from plants; representative natural products derived from marine organisms; preparation of extracts and selection of active fractions, screening strategies; separation and purification of active components; bench-top bioassays and chemical assays and structure elucidation (especially 2D-NMR spectroscopy) Student's performance will be assessed by weekly assignments on the topics discussed in lecture and exams. 3 hrs. lec.

Prerequisites: 09-219 or 09-217

09-718 Bioorganic Chemistry: Nucleic Acids and Carbohydrates

Fall: 12 units

This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of nucleic acids and carbohydrates, and their applications in chemistry, biology and medicine. Later in the course, students will have the opportunity to explore cutting-edge research in this exciting new field that bridges chemistry with biology. Students will be required to keep abreast of the current literature. In addition to standard homework assignments and examinations, students will have the opportunity to work in teams to tackle contemporary problems at the forefront of chemistry and biology. The difference between the 09-518 (9-unit) and 09-718 (12-unit) is that this latter is a graduate level course. Students signed up for 09-718 will be required to turn in an original research proposal at the end of the course, in addition to all the other assignments. 3 hrs. lec.

Prerequisites: (03-151 or 03-121) and (09-218 or 09-220)

09-719 Bioorganic Chemistry: Peptides, Proteins and Combinatorial Chemistry

Spring: 12 units

This course will introduce students to new developments in chemistry and biology, with emphasis on the synthesis, structural and functional aspects of peptides, proteins and small molecules. Basic concepts of bioorganic chemistry will be presented in the context of the current literature and students will have the opportunity to learn about the experimental methods used in various research labs. An introduction to combinatorial chemistry in the context of drug design and drug discovery will also be presented. Students will be required to keep abreast of the current literature. Homeworks and team projects will be assigned on a regular basis. The homework assignments will require data interpretation and experimental design; and team projects will give students the opportunity to work in teams to tackle contemporary problems at the interface of chemistry and biology. Students enrolled in the graduate level course (09-719) will be required to turn in an original research proposal at the end of the course, in addition to the homework assignments, midterm, and final exam that are required for the undergraduate course.

Prerequisites: (03-121 or 03-151) and (09-218 or 09-220)

09-720 Physical Inorganic Chemistry

Intermittent: 6 units

This course develops the principles of magnetochemistry and inorganic spectroscopy. Electronic absorption, magnetic circular dichroism, resonance raman, NMR, EPR, Mossbauer, magnetization and x-ray methods will be introduced with application towards the determination of electronic structures of transition metal complexes.

Prerequisites: 09-345 and 09-348 and 09-344

09-721 Metals in Biology: Function and Reactivity

Intermittent: 6 units

Metal ions play important roles in many biological processes, including photosynthesis, respiration, global nitrogen cycle, carbon cycle, antibiotics biosynthesis, gene regulation, bio-signal sensing, and DNA/RNA repair, just to name a few. Usually, metal ions are embedded in protein scaffold to form active centers of proteins in order to catalyze a broad array of chemical transformations, which are essential in supporting the biological processes mentioned above. These metal containing proteins, or metalloproteins, account for half of all proteins discovered so far. In this course, the relation between the chemical reactivity and the structure of metalloproteins will be discussed in detail. The main focus is to illustrate the geometric and electronic structure of metal centers and their interactions with the protein environment in governing the chemical reactivity of metalloproteins. The applications of these principles in designing biomimetic/bioinspired inorganic catalysts and in engineering metalloproteins bearing novel chemical reactivity will also be discussed. The basic principles of the frequently utilized physical methods in this research area will also be introduced, which include optical absorption spectroscopy, Infrared (IR) and Raman spectroscopies, M and #246;ssbauer spectroscopy, electron paramagnetic resonance (EPR), X-ray absorption and diffraction techniques. Prerequisites: (09-214 or 09-345 or 09-344 or 09-347) and 09-348

09-722 Kinetics and Mechanisms of Chemical and Enzymatic Reactions

Intermittent: 12 units

This is a practical course aimed at learning the major modern tools which are essential for investigation of mechanisms of homogeneous chemical and enzymatic reactions. Rules of formal chemical kinetics in solution are first considered followed by basic principles of kinetics of enzymatic processes including inhibition, which is a key factor in the up-to-date drug design. The relationships between electronic structures, catalytic properties, and reactivity of biologically relevant metal complexes will be provided. Electrochemical and redox features of metal complexes will be reviewed. The course includes such hot topics as Fenton chemistry, Marcus's electron transfer concept, catalysis by Collins' TAML activators of peroxides, specific and general acid/base, proximal and micellar catalysis. Mechanistic pathways of action of hydrolases, kinases, hydrogenases, oxidases, peroxidases, cytochrome P-450, and other metalloenzymes will be described. The course is supplied by the recently published text (A. D. Ryabov "Practical Kinetics and Mechanisms of Chemical and Enzymatic Reactions" Cambridge Scholars Publishing, Newcastle upon Tyne, NE6 2PA, UK) which includes all the above mentioned themes (Graduate course: 09-722, 12-units) 3 hrs. lec. Prerequisite: 09-348 Prerequisites: 09-220 and 09-345 and 09-348

09-723 Proximal Probe Techniques: New Tools for Nanoscience & Nanotechnology

Intermittent: 12 units

Proximal probe techniques are revolutionizing physical and biological sciences, owing to their ability to explore and manipulate matter at the nanoscale, and to operate in various environments (including liquids). Proximal probe techniques rely on the use of nanoscale probes, positioned and scanned in the immediate vicinity of the material surface. Their development is often viewed as a first step towards nanotechnology, since they demonstrate the feasibility of building purposeful structures one atom or one (macro)molecule at a time. This course is designed for the students of chemistry, biology physics and engineering, who are interested in the fundamentals of proximal probe techniques and in their applications in various areas, converging into a rapidly developing, interdisciplinary field of nanoscience. It will provide physical background of such basic techniques as Atomic Force Microscopy (AFM), Scanning Tunneling Microscopy (STM), and Near-Field Scanning Optical Microscopy (NSOM) and of their variants. Throughout the course, the working "virtual AFM" computer model will be assembled in classroom by each student and then used extensively to gain thorough understanding of AFM operation principles. Particular emphasis will be placed on modes of operation facilitating chemical contrast and contrast based on other material properties. (No prior experience with computer programming required). 3 hrs. lec. Prerequisites: (21-122 or 09-231 or 21-124) and (09-344 or 09-331 or 09-322 or 09-345)

09-729 Introduction to Sustainable Energy Science

Fall: 12 units

This course focuses on the chemistry aspects of sustainable energy science. It introduces the major types of inorganic and molecular materials for various important processes of energy conversion and storage, such as photovoltaics, fuel cells, water splitting, solar fuels, batteries, and CO₂ reduction. All the energy processes heavily rely on innovations in materials. This course is intended to offer perspectives on the materials/physical chemistry that are of importance in energy processes, in particular, how the atomic and electronic structures of materials impact the energy harvesting and conversion. In current energy research, intense efforts are focused on developing new strategies for achieving sustainable energy through renewable resources as opposed to the traditional oil/coal/gas compositions. This course offers students an introduction to the current energy research frontiers with a focus on solar energy conversion/ storage, electrocatalysis and artificial photosynthesis. The major types of materials to be covered include metals, semiconductors, two-dimensional materials, and hybrid perovskites, etc. The material functions in catalysis, solar cells, fuel cells, batteries, supercapacitors, hydrogen production and storage are also discussed in the course. The lectures are power-point presentation style with sufficient graphical materials to aid students to better understand the course materials. Demo experiments are designed to facilitate student learning.

Prerequisites: (09-107 or 09-105) and (33-121 or 33-141 or 33-151)

09-736 Transition Metal Catalysis for Organic and Polymer Synthesis

Intermittent: 12 units

Transition metal catalysts are invaluable in small molecule and polymer synthesis. The course will begin with a brief overview of organometallic chemistry and a discussion of fundamental organometallic reactions. Following this, a survey of some selected topics for the formation of small molecules and polymers will be presented. Some topics to be highlighted include: (1) Hydrogenation (2) Palladium Catalyzed Cross-Coupling (3) Epoxidation (4) Olefin Metathesis (5) Olefin Polymerization Prerequisites: (09-220 or 09-218) and 09-348

09-737 Medicinal Chemistry and Drug Development

Spring: 12 units

Organic chemistry is an intimate part of the drug discovery and design processes in areas that include structure determination (NMR, mass spectrometry), synthesis, and determination of mechanisms of action. Once a promising compound (i.e. a ?lead?) has been identified in the laboratory, it is rarely ready to be used in the clinic. Complications include poor bioavailability, rapid degradation, and off-target effects. Students will learn about lead compound optimization through structural variations, cell-specific targeting and pro-drug strategies. Several examples will be presented to illustrate the role played by organic chemistry in the development of drugs used to treat a range of diseases, including cancer, HIV-AIDS, bacterial infections and heart disease. Prerequisites: 09-218 or 09-220

09-738 Exposure and Risk Assessment for Environmental Pollutants

Intermittent: 12 units

Our world is full of synthetic and naturally occurring toxic chemicals, presenting an imminent but difficult-to-quantify threat for human and ecosystem health. In this papers-based course we will ask the question, "How do we decide what's 'safe'?" in the context of exposure and risk assessment for toxic environmental pollutants. We will complete a series of case studies featuring current and seminal literature, in-class activities, and project-based assignments. Each case study will focus on a distinct contaminant exposure scenario and will be linked back to the common theme of using chemistry to understand how external exposure leads to internal dose and subsequent health impacts for diverse environmental pollutants. We will discuss how knowledge generated in the laboratory can be translated and used to inform regulatory decisions. The first half of the course will focus on contaminant bioavailability, exposure, and toxic effects in aquatic organisms. In the second half of the course, we will discuss human exposure to toxic pollutants and strategies to assess risks in the human population, including the human exposure concept, -omics-based research, and strategies for discovering novel harmful contaminants. Prerequisites: 09-105 or 09-106 or 09-107

09-741 Organic Chemistry of Polymers

Spring: 12 units

A study of the synthesis and reactions of high polymers. Emphasis is on practical polymer preparation and on the fundamental kinetics and mechanisms of polymerization reactions. Topics include: relationship of synthesis and structure, step-growth polymerization, chain-growth polymerization via radical, ionic and coordination intermediates, copolymerization, discussions of specialty polymers and reactions of polymers. Students in 09-741 will take the same lectures and the same exams as those enrolled in 09-502 but, in addition, will prepare a term paper on the topic of advanced polymeric materials, to be approved by the instructor. 09-509 or 09-715, Physical Chemistry of Macromolecules, is excellent preparation for this course but is not required. 3-6 hrs. lec.

09-760 The Molecular Basis of Polymer Mechanics

Spring: 12 units

This course is a graduate level course designed to prepare students for graduate research in polymer science. Based around a laboratory component, students will learn the lab skills needed to synthesize and fully characterize novel polymer materials. The classroom component will teach the theory behind the measurements made in lab, as well as an understanding of the best experiments to learn about the properties of the material. Emphasis will be placed on current literature and technical communication (written and oral). 3 hrs lec; 3 hrs lab

09-763 Molecular Modeling and Computational Chemistry

Spring: 12 units

Computer modeling is playing an increasingly important role in chemical, biological and materials research. This course provides an overview of computational chemistry techniques including molecular mechanics, molecular dynamics, electronic structure theory and continuum medium approaches. Sufficient theoretical background is provided for students to understand the uses and limitations of each technique. An integral part of the course is hands on experience with state-of-the-art computational chemistry tools running on graphics workstations. This is the graduate equivalent of 09-563. Students enrolled in the graduate level course will complete an additional independent project. 3 hrs. lec.

09-768 Machine Learning for Molecular Sciences

Spring: 12 units

The emergence of contemporary artificial intelligence (AI) and machine learning (ML) methods has the potential to substantially alter and enhance the role of computers in science. At the heart of ML applications, lie statistical algorithms whose performance, much like that of a scholar, improves with training. There is a growing infrastructure of machine learning tools for generating, testing and refining scientific models. Such techniques are suitable for addressing complex problems that involve vast combinatorial spaces or complex processes, which conventional procedures either cannot solve or can tackle only at great computational cost. The purpose of this course is to provide a practical introduction to the core concepts and tools of machine learning in a manner easily understood and intuitive to STEM students. The course begins by covering fundamental concepts in ML, data science, and modern statistics such as the bias-variance tradeoff, overfitting, regularization, and generalization, before moving on to more advanced topics in both supervised and unsupervised learning. Topics covered in the course also include ensemble models, neural networks, modern deep learning, embedding, clustering and data visualization. Throughout the course, we emphasize application of ML methods to chemical, physical and biological data. A notable aspect of the course is the hands-on use of Python Jupyter notebooks to introduce modern ML/statistical packages.

Prerequisites: (09-231 or 09-344) and (15-110 or 15-112)

09-803 Chemistry of Gene Expression

Intermittent: 12 units

This course examines the chemical basis of biological reactions required for the propagation of genetic information stored in DNA and the organic chemistry principles behind the structure and function of nucleic acids. Main topics of lectures and class discussion will include the chemical and biochemical syntheses, properties and analyses of natural and modified nucleic acids to investigate cellular processes such as transcription, RNA splicing, other RNA regulation and translation; an introduction to the enzymatic strategies that accelerate these chemical reactions and a comparison of protein enzymes, ribozymes and other nucleic acid based enzymes in contemporary chemistry and biology. Students will learn to critically evaluate current scientific efforts that examine various aspects of chemistry and biological chemistry, the relationship between the structure and function of biomolecular systems, propose experiments to examine biological chemistry research problems and communicate these ideas and participate in scientific discussions and debates. 3 hrs. lec.

Prerequisites: (09-218 or 09-220) and (03-231 or 03-232)

Department of Mathematical Sciences

Prasad Tetali, Department Head

Dejan Slepčev, Associate Head

Jason Howell, Director of Undergraduate Studies

Location: Wean Hall 6113

www.math.cmu.edu (<http://www.math.cmu.edu>)

Mathematics provides much of the language and quantitative underpinnings of the natural and social sciences, and mathematical scientists have been responsible for the development of many of the most commonly used tools in business management as well as for laying the foundation for computational and computer science. The name of the Department of Mathematical Sciences reflects its tradition of outstanding research and teaching of applicable mathematics relating to these areas. Indeed, the Department contains highly ranked research groups in Applied Mathematics, Discrete Mathematics, Logic, and Mathematical Finance. These research strengths are reflected in the variety of options that the Department provides for its undergraduate majors.

The Department offers a B.S. degree in Mathematical Sciences. Concentrations within the degree include Mathematical Sciences, Operations Research and Statistics, Statistics, Discrete Mathematics and Logic, and Computational and Applied Mathematics.

The Mathematical Sciences concentration is the least structured of our programs, in recognition of the wide variety of interests that can be productively coupled with the study of mathematical sciences. It can be an appropriate choice for students planning for graduate study in mathematics or seeking to design their curriculum to take advantage of the many opportunities for a second major from another department in the University.

The Operations Research and Statistics Concentration prepares students to enter the area of operations research. Mathematicians with a background in operations research are especially valuable in such diverse activities as project planning, production scheduling, market forecasting and finance. Such applications are found in virtually all industrial and governmental settings.

The Statistics Concentration prepares students to contribute to a wide variety of research areas. Applications range from experimental design and data analysis in the physical and social sciences, medicine and engineering, to modeling and forecasting in business and government, to actuarial applications in the financial and insurance industries. This is also a useful second major for students planning for graduate study and research in subject areas requiring a strong statistical background.

The Discrete Mathematics and Logic Concentration provides a background in discrete mathematics, mathematical logic, and theoretical computer science. This concentration prepares the student to do research in these and related fields, or to apply their ideas elsewhere.

Finally, the Computational and Applied Mathematics Concentration provides the background needed to support the computational and mathematical analysis needs of a wide variety of businesses and industries and is well suited to students with an interest in the physical sciences and engineering.

The Department places great emphasis on the advising of students. This is critical if students are to make the most of their years at the University. Students are urged to work carefully with their advisor and other faculty to formulate their degree programs. Study abroad is encouraged, and an interested student should investigate the opportunities available in the Undergraduate Options (p. 20) section of the catalog.

Special Options

The Department offers special opportunities for the exceptionally well-prepared and intellectually ambitious student. These options are available to students from any department in the University.

Matrix Theory and Vector Analysis

For selected freshmen entering the University, the department offers the fall/spring sequence of Matrix Theory (21-242) and Vector Analysis (21-269), which include a rigorous introduction to proofs and abstract mathematics.

Typically, a student choosing this sequence has mastered the operational aspects of high school mathematics and now seeks a deeper conceptual understanding.

- Matrix Theory (21-242) is an honors version of Matrices and Linear Transformations (21-241).
- Vector Analysis (21-269) is an honors version of Multidimensional Calculus (21-268).

Admission to Matrix Theory (21-242) is based on a placement test taken at the start of the freshman year. Admission to Vector Analysis (21-269) is based on a student's performance in Matrix Theory (21-242), and on other courses taken in the Fall semester.

Mathematical Studies

The sequence of undergraduate honors courses continues with the Mathematical Studies courses, aimed primarily at sophomores. These highly demanding courses provide excellent preparation for graduate study, with many of the participants taking graduate courses as early as their junior year. Students will be expected to master material at a high level of abstraction, and to work on very challenging problems. The typical enrollment of about 15 students allows for close contact with the instructors.

- 21-235 Mathematical Studies Analysis I is an honors version of 21-355 Principles of Real Analysis I.
- 21-237 Mathematical Studies Algebra I is an honors version of 21-373 Algebraic Structures.
- 21-236 Mathematical Studies Analysis II is an honors version of 21-356 Principles of Real Analysis II.
- 21-238 Mathematical Studies Algebra II is an honors version of 21-341 Linear Algebra.

Admission to Mathematical Studies is by invitation. Interested students should apply during the spring of their freshman year. Applicants are not absolutely required to have taken 21-242 Matrix Theory or 21-269 Vector Analysis, and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses.

It is possible to take only the algebra courses or only the analysis courses. Admission to 21-236 Mathematical Studies Analysis II requires a grade of B or better in 21-235 Mathematical Studies Analysis I, and similarly, admission to 21-238 Mathematical Studies Algebra II requires a grade of B or better in 21-237 Mathematical Studies Algebra I.

Interdisciplinary Programs

Several interdisciplinary options enable a student to combine mathematics with other disciplines.

- The Bachelor of Science and Arts (p. 926) program allows a student to combine mathematics with study in any of the five schools in the College of Fine Arts.
- The Bachelor of Science in Mathematics and Economics (p. 866) is a flexible program which allows students to develop depth in both fields of study. Note: for students whose home college is Dietrich College, this major is known as the Bachelor of Science in Economics and Mathematical Sciences.
- Finally, a joint program with the Heinz College of Public Policy and Management and the Tepper School of Business leads to the degree Bachelor of Science in Computational Finance (p. 880).

Curriculum

For each concentration, we provide a list of the requirements and a suggested schedule that takes prerequisites into account. A Mathematical Sciences, Computer Science, Physics, Statistics Elective refers to any course from the Departments of Mathematical Sciences, Computer Science, Physics, or Statistics and Data Science, respectively, satisfying the following restrictions: a mathematical sciences course must be at the 21-300 level or above or 21-270 or 21-292, a computer science course must be at the 15-200 level or above, a physics course must be at the 33-300 level or above, and a statistics course must be at the 36-300 level or above and have at least 36-225 as a prerequisite.

Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose. At most a total of 9 units of 21-410/21-599 can be applied toward the Depth Elective requirement. This requires permission of both the advisor and the department.

Mathematical Sciences majors are required to complete an introductory computer science course, either 15-110 or 15-112. Students who plan to take further computer science courses must complete 15-112.

A Nontechnical Elective refers to a course in the Dietrich College of Humanities and Social Sciences requirements as described in the catalog section for the Mellon College of Science. A course listed as an Elective is a free elective with the only restriction that the maximum total of ROTC, StuCo, and Physical Education units that will be accepted for graduation is nine.

For a list of courses required for all MCS students see First Year for Science Students (p.).

B.S. in Mathematical Sciences (Mathematical Sciences)

This program is the most flexible available to our majors. The flexibility to choose eight electives within the major plus seven humanities courses and seven free electives allows the student to design a program to suit his or her individual needs and interests. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements for the Mathematics Degree are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

| Courses | Units |
|---|-------|
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| 21-127 Concepts of Mathematics | 12 |
| or 21-128 Mathematical Concepts and Proofs | |
| 21-201 Undergraduate Colloquium | 1 |
| 21-228 Discrete Mathematics | 9 |
| or 15-251 Great Ideas in Theoretical Computer Science | |
| 21-241 Matrices and Linear Transformations | 11 |
| or 21-242 Matrix Theory | |
| 21-259 Calculus in Three Dimensions | 10 |
| or 21-266 Vector Calculus for Computer Scientists | |
| or 21-268 Multidimensional Calculus | |
| or 21-269 Vector Analysis | |
| 21-260 Differential Equations | 9 |
| or 21-261 Introduction to Ordinary Differential Equations | |
| or 33-231 Physical Analysis | |
| 21-325 Probability | 9 |
| or 15-259 Probability and Computing | |
| or 36-218 Probability Theory for Computer Scientists | |
| 21-341 Linear Algebra | 9 |
| 21-355 Principles of Real Analysis I | 9-12 |
| or 21-455 Intermediate Real Analysis I | |
| 21-356 Principles of Real Analysis II | 9-10 |
| or 21-456 Intermediate Real Analysis II | |
| 21-373 Algebraic Structures | 9 |
| 117-121 | |

Forty-five units of (required) Mathematical Sciences electives (at the 21-300 level or above or 21-270 or 21-292).

Twenty-seven units of (required) Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-292, or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Mathematical Sciences Electives for Students Intending Graduate Studies

Students preparing for graduate study in mathematics should consider the following courses as Mathematical Sciences electives, choosing among them according to the desired area of graduate study. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

| Courses | Units |
|---|-------|
| 21-301 Combinatorics | 9 |
| 21-360 Differential Geometry of Curves and Surfaces | 9 |
| 21-371 Functions of a Complex Variable | 9 |
| 21-374 Field Theory | 9 |
| 21-441 Number Theory | 9 |
| 21-465 Topology | 9 |
| 21-470 Selected Topics in Analysis | 9 |
| 21-476 Introduction to Dynamical Systems | 9 |
| 21-484 Graph Theory | 9 |
| 21-602 Introduction to Set Theory I | 12 |
| 21-603 Model Theory I | 12 |
| 21-610 Algebra I | 12 |
| 21-620 Real Analysis | 6 |
| 21-621 Introduction to Lebesgue Integration | 6 |
| 21-630 Ordinary Differential Equations | 12 |
| 21-632 Introduction to Differential Equations | 12 |
| 21-640 Introduction to Functional Analysis | 12 |
| 21-651 General Topology | 12 |
| 21-660 Introduction to Numerical Analysis I | 12 |
| 21-701 Discrete Mathematics | 12 |
| 21-720 Measure and Integration | 12 |
| 21-721 Probability | 12 |
| 21-723 Advanced Real Analysis | 12 |
| 21-737 Probabilistic Combinatorics | 12 |
| 21-738 Extremal Combinatorics | 12 |

Note that courses 21-600 and above carry graduate credit. Courses at the 600 level are designed as transitional courses to graduate study. A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

Suggested Schedule for students without AP credit

Freshman Year

| | Units |
|--|-------|
| Fall | |
| 21-120 Differential and Integral Calculus | 10 |
| 21-241 Matrices and Linear Transformations | 11 |
| or 21-242 Matrix Theory | |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 76-101 Interpretation and Argument | 9 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| xx-xxx Technical Breadth Requirement | 9 |
| 48 | |
| Spring | |
| 15-110 Principles of Computing | 10 |
| or 15-112 Fundamentals of Programming and Computer Science | |
| 21-127 Concepts of Mathematics | 12 |
| or 21-128 Mathematical Concepts and Proofs | |
| 21-122 Integration and Approximation | 10 |
| xx-xxx Technical Breadth Requirement | 9 |
| xx-xxx Nontechnical Elective | 9 |
| 50 | |

Sophomore Year

| Fall | | Units |
|-----------|---|-----------|
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-268 | Multidimensional Calculus | 11 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |

| Spring | | Units |
|--------|---|-----------|
| 21-261 | Introduction to Ordinary Differential Equations | 10 |
| 21-373 | Algebraic Structures | 9 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 47 |

Junior Year

| Fall | | Units |
|-----------|--|-----------|
| 21-355 | Principles of Real Analysis I | 9 |
| or 21-455 | Intermediate Real Analysis I | |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 46 |

| Spring | | Units |
|-----------|--|-----------|
| 21-341 | Linear Algebra | 9 |
| 21-356 | Principles of Real Analysis II | 9 |
| or 21-456 | Intermediate Real Analysis II | |
| 21-xxx | Mathematical Sciences Elective | 9 |
| xx-xxx | Science and Society Course | 6 |
| xx-xxx | Cultural/Global Understanding Elective | 9 |
| | | 42 |

Senior Year

| Fall | | Units |
|--------|-------------------------------------|-----------|
| 21-xxx | Mathematical Sciences Elective | 9 |
| 21-xxx | Mathematical Sciences Elective | 9 |
| 38-110 | ENGAGE in Service ¹ | 1 |
| 38-220 | ENGAGE in the Arts ¹ | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 40 |

| Spring | | Units |
|--------|--------------------------------|-----------|
| 21-xxx | Mathematical Sciences Elective | 9 |
| 21-xxx | Mathematical Sciences Elective | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

Minimum number of units required for degree: 360

Suggested Schedule for Students with AP Credit

Freshman Year

| Fall | | Units |
|--------|-------------------------------------|-------|
| 21-241 | Matrices and Linear Transformations | 11 |

| | | |
|-----------|-----------------------------------|-----------|
| or 21-242 | Matrix Theory | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 76-101 | Interpretation and Argument | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| xx-xxx | Technical Breadth Requirements | 9 |
| | | 50 |

| Spring | | Units |
|-----------|--|-----------|
| 15-110 | Principles of Computing | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-268 | Multidimensional Calculus | 10 |
| or 21-269 | Vector Analysis | |
| xx-xxx | Nontechnical Elective | 9 |
| | | 38 |

Sophomore Year

| Fall | | Units |
|-----------|--|-----------|
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 21-373 | Algebraic Structures | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

| Spring | | Units |
|-----------|---|-----------|
| 21-261 | Introduction to Ordinary Differential Equations | 10 |
| 21-355 | Principles of Real Analysis I | 9 |
| or 21-455 | Intermediate Real Analysis I | |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 38 |

Junior Year

| Fall | | Units |
|-----------|--------------------------------------|-----------|
| 21-356 | Principles of Real Analysis II | 9 |
| or 21-456 | Intermediate Real Analysis II | |
| 21-xxx | Mathematical Sciences Elective | 9 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Cultural/Global Understanding Course | 9 |
| xx-xxx | Free Elective | 9 |
| | | 37 |

| Spring | | Units |
|--------|--------------------------------|-----------|
| 21-341 | Linear Algebra | 9 |
| 21-xxx | Mathematical Sciences Elective | 9 |
| xx-xxx | Science and Society Course | 6 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 42 |

Senior Year

| Fall | | Units |
|--------|-------------------------------------|-------|
| 21-xxx | Mathematical Sciences Elective | 9 |
| 21-xxx | Mathematical Sciences Elective | 9 |
| 38-110 | ENGAGE in Service ¹ | 1 |
| 38-220 | ENGAGE in the Arts ¹ | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |

| | | |
|--------|--------------------------------|-----------|
| xx-xxx | Free Elective | 9 |
| | | 49 |
| Spring | | Units |
| 21-xxx | Mathematical Sciences Elective | 9 |
| 21-xxx | Mathematical Sciences Elective | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Operations Research and Statistics)

An operations research professional employs quantitative and computational skills toward enhancing the function of an organization or process. Students choosing this concentration will develop problem-solving abilities in mathematical and statistical modeling and computer-based simulation in areas such as network design, transportation scheduling, allocation of resources and optimization. In addition to courses in mathematics and statistics, a basic background in economics and accounting is included. Since problems in business and industry are often solved by teams, the curriculum typically includes group projects. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences College. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the concentration in Operations Research and Statistics are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

| Courses | | Units |
|-----------|---|------------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-292 | Operations Research I | 9 |
| 21-369 | Numerical Methods | 12 |
| 21-393 | Operations Research II | 9 |
| | | 102 |

Statistics Courses (required)

| Courses | | Units |
|-----------|--|-----------|
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| | | 45 |

Economics, Business, and Computer Science Courses (required)

| Courses | | Units |
|-----------|------------------------------|-----------|
| 15-110 | Principles of Computing | 10 |
| 70-122 | Introduction to Accounting | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| or 73-240 | Intermediate Macroeconomics | |
| | | 46 |

Depth Electives (required)

Forty-five units of (required) depth electives, to be chosen from the list below. The courses 21-355 and 21-455 are particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

| Courses | | Units |
|-----------|--|-------|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 10-605 | Machine Learning with Large Datasets | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-301 | Combinatorics | 9 |
| 21-321 | Interactive Theorem Proving | 9 |
| 21-341 | Linear Algebra | 9 |
| 21-355 | Principles of Real Analysis I | 9-12 |
| or 21-455 | Intermediate Real Analysis I | |
| 21-356 | Principles of Real Analysis II | 9 |
| or 21-456 | Intermediate Real Analysis II | |
| 21-366 | Topics in Applied Mathematics | 9 |
| 21-370 | Discrete Time Finance | 9 |
| 21-373 | Algebraic Structures | 9 |
| 21-377 | Monte Carlo Simulation for Finance | 9 |
| 21-378 | Mathematics of Fixed Income Markets | 9 |
| 21-387 | Monte Carlo Methods and Applications | 9 |
| 21-420 | Continuous-Time Finance | 9 |
| 21-484 | Graph Theory | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 70-371 | Operations Management | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 70-471 | Supply Chain Management | 9 |

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102, 73-103, 73-230, and 73-240 satisfy requirements from the MCS general education core.

Suggested Schedule

Freshman Year

| Fall | | Units |
|-----------|-------------------------------------|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 76-101 | Interpretation and Argument | 9 |

| | | |
|-----------|--|-----------|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| xx-xxx | Technical Breadth Requirement | 9 |
| | | 48 |
| Spring | | Units |
| 15-110 | Principles of Computing | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 50 |

Sophomore Year

| | | |
|-----------|---|-----------|
| Fall | | Units |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 73-102 | Principles of Microeconomics | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| | | 38 |
| Spring | | Units |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-292 | Operations Research I | 9 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| 70-122 | Introduction to Accounting | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 46 |

Junior Year

| | | |
|-----------|--|-----------|
| Fall | | Units |
| 21-369 | Numerical Methods | 12 |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 73-103 | Principles of Macroeconomics | 9 |
| xx-xxx | Depth Elective | 9 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| | | 40 |
| Spring | | Units |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 73-230 | Intermediate Macroeconomics | 9 |
| or 73-240 | Intermediate Macroeconomics | |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Science and Society Course | 6 |
| xx-xxx | Cultural/Global Understanding Course | 9 |
| | | 51 |

Senior Year

| | | |
|--------|-------------------------------------|-------|
| Fall | | Units |
| 21-393 | Operations Research II | 9 |
| 36-401 | Modern Regression | 9 |
| xx-xxx | Depth Elective | 9 |
| 38-110 | ENGAGE in Service ¹ | 1 |
| 38-220 | ENGAGE in the Arts ¹ | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Nontechnical Elective | 9 |

| | | |
|--------|---------------|-----------|
| xx-xxx | Free Elective | 9 |
| | | 49 |

| | | |
|--------|------------------------------------|-----------|
| Spring | | Units |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Statistics)

Statistics is concerned with the process by which inferences are made from data. Statistical methods are essential to research in a wide variety of scientific disciplines. For example, principles of experimental design that assist chemists in improving their yields also help poultry farmers grow bigger chickens. Similarly, time series analysis is used to better understand radio waves from distant galaxies, hormone levels in the blood, and concentrations of pollutants in the atmosphere. This diversity of application is an exciting aspect of the field, and it is one reason for the current demand for well-trained statisticians.

The courses 15-259 Probability and Computing and 36-226 Introduction to Statistical Inference taken in the junior year serve as the basis for all further statistics courses. The course 21-325 is a more mathematical alternative to 15-259.

The Statistics Concentration is jointly administered by the Department of Mathematical Sciences and the Department of Statistics and Data Science. The Department of Statistics and Data Science considers applications for the master's program from undergraduates in the junior year. Students who are accepted are expected to finish their undergraduate studies, using some electives in the senior year to take courses recommended by the Department of Statistics and Data Science. This will ensure a strong background to permit completion of the master's program in one year beyond the baccalaureate. Students choosing this concentration may not pursue an additional minor in Statistics in the Dietrich College of Humanities and Social Sciences. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies. The requirements for the Statistics Concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

| Courses | Units | |
|-----------|---|------------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-292 | Operations Research I | 9 |
| 21-369 | Numerical Methods | 12 |
| 21-393 | Operations Research II | 9 |
| | | 102 |

Statistics Courses (required)

| Courses | Units | |
|---------|-------------|---|
| 21-325 | Probability | 9 |

| | | |
|-----------|--|-----------|
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| | | 45 |

Economics and Computer Science Courses (required)

| Courses | | Units |
|---------|--|-----------|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 73-102 | Principles of Microeconomics | 9 |
| | | 33 |

Depth Electives (required)

Forty-five units of (required) depth electives, including at least nine units in statistics, to be chosen from the list below. The courses 21-355 and 21-455 are particularly recommended for a student planning to pursue graduate work. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

| Courses | | Units |
|-----------|--|-------|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 10-605 | Machine Learning with Large Datasets | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-321 | Interactive Theorem Proving | 9 |
| 21-341 | Linear Algebra | 9 |
| 21-355 | Principles of Real Analysis I | 9-12 |
| or 21-455 | Intermediate Real Analysis I | |
| 21-356 | Principles of Real Analysis II | 9 |
| or 21-456 | Intermediate Real Analysis II | |
| 21-366 | Topics in Applied Mathematics | 9 |
| 21-370 | Discrete Time Finance | 9 |
| 21-373 | Algebraic Structures | 9 |
| 21-377 | Monte Carlo Simulation for Finance | 9 |
| 21-378 | Mathematics of Fixed Income Markets | 9 |
| 21-387 | Monte Carlo Methods and Applications | 9 |
| 21-420 | Continuous-Time Finance | 9 |
| 21-484 | Graph Theory | 9 |
| 36-461 | Special Topics: Statistical Methods in Epidemiology | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Note that 73-102 satisfies a requirement from the MCS core.

Suggested Schedule

Freshman Year

| Fall | | Units |
|-----------|-------------------------------------|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 76-101 | Interpretation and Argument | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |

| | | |
|-----------|--|-----------|
| xx-xxx | Life/Physical Sciences Course | 9 |
| | | 48 |
| Spring | | Units |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-122 | Integration and Approximation | 10 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Physical/Life Sciences Course | 9 |
| | | 52 |

Sophomore Year

| Fall | | Units |
|-----------|---|-----------|
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 73-102 | Principles of Microeconomics | 9 |
| xx-xxx | Technical Breadth Requirements | 9 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 47 |

| Spring | | Units |
|-----------|---|-----------|
| 15-122 | Principles of Imperative Computation | 12 |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-292 | Operations Research I | 9 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 49 |

Junior Year

| Fall | | Units |
|-----------|--|-----------|
| 21-369 | Numerical Methods | 12 |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Depth Elective | 9 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Nontechnical Elective | 9 |
| | | 49 |

| Spring | | Units |
|--------|---------------------------------------|-----------|
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Science and Society Course | 6 |
| xx-xxx | Cultural/Global Understanding Course | 9 |
| | | 42 |

Senior Year

| Fall | | Units |
|--------|-------------------------------------|-------|
| 21-393 | Operations Research II | 9 |
| 36-401 | Modern Regression | 9 |
| xx-xxx | Depth Elective | 9 |
| 38-110 | ENGAGE in Service ¹ | 1 |
| 38-220 | ENGAGE in the Arts ¹ | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |

| | | |
|--------|------------------------------------|-----------|
| xx-xxx | Nontechnical Elective | 9 |
| | | 40 |
| Spring | | Units |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

Minimum number of units required for degree: 360

B.S. in Mathematical Sciences (Discrete Mathematics and Logic)

Discrete mathematics is the study of finite and countable structures and algorithms for the manipulation and analysis of such structures, while mathematical logic is the study of axiomatic systems and their mathematical applications. Both are flourishing research areas and have close ties with computer science.

The Discrete Mathematics and Logic Concentration provides a firm background in discrete mathematics and mathematical logic, together with the elements of theoretical computer science. It prepares the student to pursue research in these fields, or to apply their ideas in the many disciplines (ranging from philosophy to hardware verification) where such ideas have proved relevant. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Discrete Mathematics and Logic Concentration are:

Mathematical Sciences and Computer Science Courses (required)

The alternative course 21-242 is particularly recommended for a student planning to pursue graduate work. Students who plan to pursue graduate study in mathematical logic are strongly advised to take 21-300 Basic Logic.

| Courses | | Units |
|-----------|--|-------|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-300 | Basic Logic | 9 |
| or 15-317 | Constructive Logic | |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-301 | Combinatorics | 9 |
| 21-341 | Linear Algebra | 9 |
| 21-355 | Principles of Real Analysis I | 9-12 |
| or 21-455 | Intermediate Real Analysis I | |
| 21-373 | Algebraic Structures | 9 |

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Computer Science electives (required)

Any two courses at the 300 level or above. The following are specifically suggested:

| | | |
|--------|---|----|
| 15-312 | Foundations of Programming Languages | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| 15-453 | Formal Languages, Automata, and Computability | 9 |

Students pursuing this concentration who minor in Computer Science must take two additional Computer Science courses at the 300 level or above to avoid excessive double counting.

Mathematical Sciences Electives (required)

Sixty-three units of mathematical sciences electives, to be chosen from list 1 and 2 below, including at least twenty-seven units chosen from list 1. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

List 1 (Discrete Mathematics and Logic Electives)

| Courses | | Units |
|---------|------------------------------|-------|
| 15-259 | Probability and Computing | 12 |
| 21-321 | Interactive Theorem Proving | 9 |
| 21-322 | Topics in Formal Mathematics | 9 |
| 21-325 | Probability | 9 |
| 21-329 | Set Theory | 9 |
| 21-374 | Field Theory | 9 |
| 21-400 | Intermediate Logic | 9 |
| 21-441 | Number Theory | 9 |
| 21-484 | Graph Theory | 9 |
| 21-602 | Introduction to Set Theory I | 12 |
| 21-603 | Model Theory I | 12 |
| 21-610 | Algebra I | 12 |
| 21-701 | Discrete Mathematics | 12 |
| 80-305 | Game Theory | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |

List 2 (General Mathematics Electives)

| Courses | | Units |
|-----------|---|-------|
| 21-259 | Calculus in Three Dimensions | 10-11 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9-10 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-292 | Operations Research I | 9 |
| 21-356 | Principles of Real Analysis II | 9 |
| or 21-456 | Intermediate Real Analysis II | |
| 21-366 | Topics in Applied Mathematics | 9 |
| 21-369 | Numerical Methods | 12 |
| 21-370 | Discrete Time Finance | 9 |
| 21-371 | Functions of a Complex Variable | 9 |
| 21-387 | Monte Carlo Methods and Applications | 9 |
| 21-393 | Operations Research II | 9 |
| 21-420 | Continuous-Time Finance | 9 |
| 21-470 | Selected Topics in Analysis | 9 |
| 21-476 | Introduction to Dynamical Systems | 9 |
| 21-410 | Research Topics in Mathematical Sciences | 9 |

Any graduate course in mathematics at the 600 and 700 level not included in List 1.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

Suggested Schedule

Freshman Year

| Fall | | Units |
|--------|--|-------|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 76-101 | Interpretation and Argument | 9 |
| 99-101 | Computing @ Carnegie Mellon | 3 |
| xx-xxx | Life/Physical Sciences Course | 9 |

| Spring | | Units |
|-----------|--------------------------------------|-------|
| 15-122 | Principles of Imperative Computation | 12 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| xx-xxx | Technical Breadth Requirement | 9 |

54**Sophomore Year**

| Fall | | Units |
|-----------|--------------------------------------|-------|
| 15-150 | Principles of Functional Programming | 12 |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-268 | Multidimensional Calculus | 10 |
| or 21-269 | Vector Analysis | |
| 21-301 | Combinatorics | 9 |
| 21-373 | Algebraic Structures | 9 |
| xx-xxx | Nontechnical Elective | 9 |

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| Spring | | Units |
|--------|--|-------|
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx | Discrete Math/Logic Elective | 9 |
| xx-xxx | Mathematics Elective | 9 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |

49**Junior Year**

| Fall | | Units |
|-----------|-------------------------------------|-------|
| 15-xxx | Computer Science Elective | 9 |
| 21-300 | Basic Logic | 9 |
| or 15-317 | Constructive Logic | |
| 21-355 | Principles of Real Analysis I | 9 |
| or 21-455 | Intermediate Real Analysis I | |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx | Technical Breadth Requirement | 9 |
| xx-xxx | Nontechnical Elective | 9 |

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| Spring | | Units |
|--------|--------------------------------------|-------|
| 15-xxx | Computer Science Elective | 9 |
| 21-341 | Linear Algebra | 9 |
| xx-xxx | Science and Society Course | 6 |
| xx-xxx | Nontechnical Elective | 9 |
| xx-xxx | Cultural/Global Understanding Course | 9 |

42**Senior Year**

| Fall | | Units |
|--------|-------------------------------------|-------|
| xx-xxx | Discrete Math/Logic Elective | 9 |
| xx-xxx | Mathematics Elective | 9 |
| xx-xxx | Mathematics Elective | 9 |
| 38-110 | ENGAGE in Service ¹ | 1 |
| 38-220 | ENGAGE in the Arts ¹ | 2 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Free Elective | 9 |

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| Spring | | Units |
|--------|------------------------------|-------|
| xx-xxx | Discrete Math/Logic Elective | 9 |
| xx-xxx | Mathematics Elective | 9 |
| xx-xxx | Mathematics Elective | 9 |

| xx-xxx | Free Elective | 9 |
|--------|---------------|-----------|
| | | 36 |

Minimum number of units required for degree: 360

**B.S. in Mathematical Sciences
(Computational and Applied Mathematics)**

This concentration is designed to prepare students for careers in business or industry which require significant analytical, computational and problem solving skills. It also prepares students with interest in computational and applied mathematics for graduate school.

The students in this concentration develop skills to choose the right framework to quantify or model a problem, analyze it, simulate and in general use appropriate techniques for carrying the effort through to an effective solution. The free electives allow the student to develop an interest in a related area by completing a minor in another department, such as Engineering Studies, Economics, Information Systems or Business Administration. By default, students must fulfill all the requirements of the catalog of the year they entered CMU. Students who wish to be considered for a subsequent catalog may submit a request to the Director of Undergraduate Studies.

The requirements for the Computational and Applied Mathematics Concentration are:

Mathematical Sciences Courses (required)

The alternative courses 21-242, 21-261, and 21-268 (or 21-269) are particularly recommended for a student planning to pursue graduate work.

| Courses | | Units |
|-----------|--|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |
| 21-355 | Principles of Real Analysis I | 9-12 |
| or 21-455 | Intermediate Real Analysis I | |
| 21-369 | Numerical Methods | 12 |
| 21-469 | Computational Introduction to Partial Differential Equations | 12 |

114-117**Depth Electives (required)**

Students must take twenty-seven units of depth electives, to be chosen from the list below. Exceptions to the elective requirements for each concentration of the B.S. degree in Mathematical Sciences require prior approval from the student's academic advisor, the Director of Undergraduate Studies in Mathematical Sciences, or the Department Head of Mathematical Sciences.

| Courses | | Units |
|-----------|---|-------|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-292 | Operations Research I | 9 |
| 21-344 | Numerical Linear Algebra | 9 |
| 21-380 | Introduction to Mathematical Modeling | 9 |
| 21-435 | Applied Harmonic Analysis | 9 |

Computer Science Courses (required)

| Courses | Units |
|---|-------|
| 15-122 Principles of Imperative Computation | 12 |

Mathematics Electives (required)

Students must take 27 units either from the three remaining courses from the depth electives or from the list below:

| Courses | Units |
|--|-------|
| 21-321 Interactive Theorem Proving | 9 |
| 21-322 Topics in Formal Mathematics | 9 |
| 21-341 Linear Algebra | 9 |
| 21-356 Principles of Real Analysis II or 21-456 Intermediate Real Analysis II | 9 |
| 21-366 Topics in Applied Mathematics | 9 |
| 21-370 Discrete Time Finance | 9 |
| 21-371 Functions of a Complex Variable | 9 |
| 21-373 Algebraic Structures | 9 |
| 21-377 Monte Carlo Simulation for Finance | 9 |
| 21-378 Mathematics of Fixed Income Markets | 9 |
| 21-387 Monte Carlo Methods and Applications | 9 |
| 21-393 Operations Research II | 9 |
| 21-420 Continuous-Time Finance | 9 |
| 21-470 Selected Topics in Analysis | 9 |
| 21-476 Introduction to Dynamical Systems | 9 |
| 21-484 Graph Theory | 9 |
| 21-620 Real Analysis | 6 |
| 21-621 Introduction to Lebesgue Integration | 6 |
| 21-630 Ordinary Differential Equations | 12 |
| 21-632 Introduction to Differential Equations | 12 |
| 21-640 Introduction to Functional Analysis | 12 |
| 21-651 General Topology | 12 |
| 21-660 Introduction to Numerical Analysis I | 12 |
| 21-690 Methods of Optimization | 12 |
| 21-720 Measure and Integration | 12 |
| 21-721 Probability | 12 |
| 21-723 Advanced Real Analysis | 12 |
| 21-732 Partial Differential Equations I | 12 |
| 21-832 Partial Differential Equations II | 12 |

Students must take nine additional units of Mathematical Sciences (at the 21-300 level or above or 21-270 or 21-292), or Computer Science (at the 15-200 level or above), or Physics (at the 33-300 level or above), or Statistics (must be at the 36-300 level or above and have at least 36-225 as a prerequisite) electives.

21-366 Topics in Applied Mathematics and 21-470 Selected Topics in Analysis have content that varies from year to year. These courses can be taken more than once (with permission).

Note that courses 21-600 and above carry graduate credit. 600-level courses are designed as transitional courses to graduate study.

A student preparing for graduate study should also consider undertaking independent work. The Department offers 21-410 Research Topics in Mathematical Sciences and 21-599 Undergraduate Reading and Research for this purpose.

Courses 21-700 and above can be used with the permission of both the advisor and the department.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units).

Students not in MCS are required to take 15-110 Principles of Computing (10 units).

Suggested Schedule**Freshman Year**

| Fall | Units |
|---|-------|
| 21-120 Differential and Integral Calculus | 10 |
| 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory | 11 |

| | |
|--|-----------|
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 76-101 Interpretation and Argument | 9 |
| xx-xxx Technical Breadth Requirement | 9 |
| | 45 |

| Spring | Units |
|--|-----------|
| 21-122 Integration and Approximation | 10 |
| 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs | 12 |
| 21-228 Discrete Mathematics | 9 |
| xx-xxx Technical Breadth Requirement | 9 |
| xx-xxx Nontechnical Elective | 9 |
| | 49 |

Sophomore Year

| Fall | Units |
|---|-----------|
| 15-112 Fundamentals of Programming and Computer Science | 12 |
| 21-201 Undergraduate Colloquium | 1 |
| 21-268 Multidimensional Calculus or 21-269 Vector Analysis | 10 |
| xx-xxx Technical Breadth Requirement | 9 |
| xx-xxx Nontechnical Elective | 9 |
| | 41 |

| Spring | Units |
|--|-----------|
| 15-122 Principles of Imperative Computation | 12 |
| 21-261 Introduction to Ordinary Differential Equations | 10 |
| 21-355 Principles of Real Analysis I or 21-455 Intermediate Real Analysis I | 9 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| xx-xxx Technical Breadth Requirement | 9 |
| xx-xxx Nontechnical Elective | 9 |
| | 50 |

Junior Year

| Fall | Units |
|---|-----------|
| 21-325 Probability or 15-259 Probability and Computing or 36-218 Probability Theory for Computer Scientists | 9 |
| 21-356 Principles of Real Analysis II or 21-456 Intermediate Real Analysis II | 9 |
| 38-330 ENGAGE in Wellness: Looking Outward | 1 |
| xx-xxx Nontechnical Elective | 9 |
| xx-xxx Free Elective | 9 |
| | 37 |

| Spring | Units |
|---|-----------|
| 21-369 Numerical Methods | 12 |
| xx-xxx Mathematics Elective | 9 |
| xx-xxx Depth Elective | 9 |
| xx-xxx Science and Society Course | |
| xx-xxx Cultural/Global Understanding Elective | 9 |
| xx-xxx Free Elective | 9 |
| | 48 |

Senior Year

| Fall | Units |
|--|-----------|
| xx-xxx Mathematics Elective | 9 |
| xx-xxx Mathematics Elective | 9 |
| xx-xxx Depth Elective | 9 |
| 38-110 ENGAGE in Service ¹ | 1 |
| 38-220 ENGAGE in the Arts ¹ | 2 |
| 38-430 ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx Free Elective | 9 |
| xx-xxx Free Elective | 9 |
| | 49 |

| Spring | | Units |
|--------|----------------------|-----------|
| xx-xxx | Mathematics Elective | 9 |
| xx-xxx | Depth Elective | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 45 |

Minimum number of units required for degree: 360

B.A. in Mathematical Sciences

Mathematical Sciences Courses (required)

| | | |
|-----------|---|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-201 | Undergraduate Colloquium | 1 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |

Forty-five units of Mathematical Sciences electives (at the 21-300 level or above; or 21-270 or 21-292).

Twenty-seven units of Mathematical Sciences (at the 21-300 level or above; or 21-270 or 21-292), or Computer Science (at the 15-200 level or above; or Physics (at the 33-300 level or above; or Statistics (at the 36-300 level or above; and have at least 36-225 as a prerequisite) electives.

MCS General Education (required)

MCS humanities, social sciences, and science core (114 units)

¹ Students must register for this course no later than their penultimate semester. But, work for this course can be begun in any semester prior to registration.

Additional Major Requirements

All concentrations within the B.S. in Mathematical Sciences are available as an additional major to students majoring in other departments. The requirements for the additional majors are the same as those for the B.S. degrees, except that the MCS General Education requirements are waived.

In order to avoid double-counting issues, students are encouraged to consult with their degree advisor as well as their additional major advisor.

Please visit the Department of Mathematical Sciences Undergraduate FAQ website (<https://www.cmu.edu/math/undergrad/faq.html>) (under "Admissions") for further details

The Minor in Mathematical Sciences

The Minor includes six courses. 21-127 Concepts of Mathematics is a prerequisite for 21-228 and recommended for 21-241. The minimum preparation required for 21-355 Principles of Real Analysis I is 21-122 and 21-127 or equivalent courses. Please see below if you are a Computational Finance major.

| | | |
|-----------|---|----|
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| or 15-151 | Mathematical Foundations for Computer Science | |

| | | |
|-----------|--|------|
| 21-228 | Discrete Mathematics | 9-12 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-355 | Principles of Real Analysis I | 9 |
| 21-xxx | Mathematical Sciences Elective (300-level or higher) | |
| 21-xxx | Mathematical Sciences Elective (300-level or higher) | |

To avoid excessive double counting, the two Mathematical Sciences Electives may not also count toward the student's major.

Computational Finance majors who declare a minor in Mathematical Sciences should take the following six courses:

Required courses are:

| | | |
|-----------|---|----|
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| or 15-151 | Mathematical Foundations for Computer Science | |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-355 | Principles of Real Analysis I | 9 |
| 21-325 | Probability | 9 |
| or 15-259 | Probability and Computing | |
| or 36-218 | Probability Theory for Computer Scientists | |

Nine units of Mathematical Sciences Electives, to be chosen from the following list:

| | | |
|--------|----------------------|---|
| 21-300 | Basic Logic | 9 |
| 21-301 | Combinatorics | 9 |
| 21-329 | Set Theory | 9 |
| 21-373 | Algebraic Structures | 9 |
| 21-484 | Graph Theory | 9 |

*Students who take 21-325 (or 15-259 or 36-218) to fulfill their BSCF requirements should take an additional 21-3xx elective to avoid excessive double counting.

The Minor in Discrete Mathematics and Logic

This minor develops the fundamentals of discrete mathematics and logic necessary to understand the mathematical foundations of many computer related disciplines. Required courses are:

| | | |
|-----------|---|------|
| 21-228 | Discrete Mathematics ¹ | 9-12 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-300 | Basic Logic | 9 |
| or 15-317 | Constructive Logic | |
| 21-301 | Combinatorics | 9 |

¹21-127 Concepts of Mathematics is a prerequisite for 21-228.

Twenty-seven units of Mathematical Sciences Electives, to be chosen from the following two groups (at least nine units from each group).

| | | |
|----------------------------------|------------------------------|----|
| Logic | | |
| 21-321 | Interactive Theorem Proving | 9 |
| 21-329 | Set Theory | 9 |
| 21-400 | Intermediate Logic | 9 |
| 21-602 | Introduction to Set Theory I | 12 |
| 21-603 | Model Theory I | 12 |
| 80-305 | Game Theory | 9 |
| 80-315 | Modal Logic | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |
| Algebra and Discrete Mathematics | | |
| 21-341 | Linear Algebra | 9 |
| 21-373 | Algebraic Structures | 9 |

| | | |
|--------|----------------------|----|
| 21-374 | Field Theory | 9 |
| 21-441 | Number Theory | 9 |
| 21-484 | Graph Theory | 9 |
| 21-610 | Algebra I | 12 |
| 21-701 | Discrete Mathematics | 12 |

The Honors Degree Program

This demanding program qualifies the student for an additional degree, the Master of Science in Mathematical Sciences. Admission to the Honors Degree Program is selective and interested students should apply for admission during their junior year. In the application process, the Department will hold to the same high standards which apply to admission to any graduate program. Applicants are not absolutely required to have taken the Mathematical Studies courses and may be admitted on the basis of exceptionally strong performance in non-honors mathematics courses or of accomplishments in research. Applicants are expected to have completed the Mathematical Studies sequences in Algebra and Analysis or 21-355/21-356 and 21-373/21-341 prior to application. 21-455/21-456 may be taken in place of 21-355/21-356.

In order to complete the Honors Degree Program, students must complete five mathematics graduate courses with grades of B or better and write an honors thesis. At the time of admission, students will declare a timetable on which they plan to take the graduate courses, do the research required for the thesis, and write up their work: this timetable can naturally be adjusted as required. At most, one of these five graduate courses may be applied towards the student's bachelor degree program.

At least three graduate courses must come from the list of Basic Examinations courses (<https://www.cmu.edu/math/grad/phd/requirements.html>).

Currently these are listed as:

- General Topology (21-651)
- Functional Analysis (21-640)
- Measure and Integration (21-720)
- Probability (21-721)
- Discrete Mathematics (21-701)
- Probabilistic Combinatorics (21-737)
- Set Theory (21-602)
- Algebra (21-610)
- Model Theory (21-603)
- Differential Equations (21-632)

By special permission of the department, one graduate course with sufficient mathematical content offered in another department may be counted. The honors thesis may either be research-based or expository: expository theses must be at a high mathematical level, at least that of a second-year graduate course. Students should plan on finding a thesis advisor by the end of their junior year. Students are required to take 21-901 Master's Degree Research during their senior year, subject to the following conditions:

1. Students must complete a minimum of 15 units of 21-901 to earn the MS degree.
2. Students who have not defended their thesis by the Add Course Deadline during each of their last two semesters must register for a minimum of 3 units of 21-901 for that semester.
3. Students may not overload more than 66 units while taking 21-901.

The Master of Science degree in Mathematical Sciences may be earned together with a Bachelor of Science from another department.

Faculty

NOHA ABDELGHANY, Assistant Teaching Professor – Ph.D., Western Michigan University; Carnegie Mellon, 2022–

THERESA ANDERSON, Assistant Professor – Ph.D., Brown University; Carnegie Mellon, 2022–

JEREMY AVIGAD, Professor – Ph.D., University of California, Berkeley; Carnegie Mellon, 1996–

THOMAS BOHMAN, Professor – Ph.D., Rutgers University; Carnegie Mellon, 1998–

BORIS BUKH, Professor – Ph.D., Princeton University; Carnegie Mellon, 2012–

CLINTON CONLEY, Associate Professor – Ph.D., University of California Los Angeles; Carnegie Mellon, 2014–

JAMES CUMMINGS, Professor – Ph.D., Cambridge University; Carnegie Mellon, 1996–

HASAN DEMIRKOPARAN, Teaching Professor of Mathematics – Ph.D., Michigan State University; Carnegie Mellon, 2005–

LAYAN EL HAJJ, Associate Teaching Professor – Ph.D., McGill University; Carnegie Mellon, 2023–

TIMOTHY FLAHERTY, Associate Teaching Professor – Ph.D., University of Pittsburgh; Carnegie Mellon, 1999–

IRENE FONSECA, Kavčič-Moura University Professor of Mathematics – Ph.D., University of Minnesota; Carnegie Mellon, 1987–

FLORIAN FRICK, Associate Professor – Ph.D., Technical University of Berlin; Carnegie Mellon, 2018–

ALAN FRIEZE, Orion Hoch, S 1952, University Professor of Mathematical Sciences – Ph.D., University of London; Carnegie Mellon, 1987–

IRINA GHEORGHICIUC, Associate Teaching Professor – Ph.D., University of Pennsylvania; Carnegie Mellon, 2007–

RAMI GROSSBERG, Professor – Ph.D., Hebrew University of Jerusalem; Carnegie Mellon, 1988–

DAVID HANDRON, Associate Teaching Professor – Ph.D., Rice University; Carnegie Mellon, 1999–

JASON HOWELL, Teaching Professor & Director of Undergraduate Studies – Ph.D., Clemson University; Carnegie Mellon, 2017–

WILLIAM HRUSA, Professor – Ph.D., Brown University; Carnegie Mellon, 1982–

GAUTAM IYER, Professor – Ph.D., University of Chicago; Carnegie Mellon, 2009–

GREGORY JOHNSON, Associate Teaching Professor – Ph.D., University of Maryland; Carnegie Mellon, 2009–

NIRAJ KHARE, Associate Teaching Professor – Ph.D., Ohio State University; Carnegie Mellon, 2014–

DAVID KINDERLEHRER, Alumni Professor of Mathematical Sciences – Ph.D., University of California at Berkeley; Carnegie Mellon, 1990–

DMITRY KRAMKOV, Mellon College of Science Professor of Mathematical Finance – Ph.D., Steklov Mathematical Institute; Carnegie Mellon, 2000–

MARTIN LARSSON, Professor – Ph.D., Cornell University; Carnegie Mellon, 2019–

GIOVANNI LEONI, Professor – Ph.D., University of Minnesota; Carnegie Mellon, 2002–

PO-SHEN LOH, Professor – Ph.D., Princeton University; Carnegie Mellon, 2009–

JOHN MACKEY, Teaching Professor – Ph.D., University of Hawaii; Carnegie Mellon, 2003–

ROBIN NEUMAYER, Assistant Professor – Ph.D., The University of Texas at Austin; Carnegie Mellon, 2021–

CLIVE NEWSTEAD, Assistant Teaching Professor – PhD, Carnegie Mellon University; Carnegie Mellon, 2018–

DAVID OFFNER, Associate Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–

MARION OLIVER, Teaching Professor – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–

WESLEY PEGDEN, Professor – Ph.D., Rutgers University; Carnegie Mellon, 2013–

AGOSTON PISZTORA, Associate Professor – Ph.D., ETH Zurich; Carnegie Mellon, 1996–

DYLAN QUINTANA, Assistant Teaching Professor – Ph.D., University of Chicago; Carnegie Mellon, 2023–

MATTHEW ROSENZWEIG, Assistant Professor – Ph.D., University of Texas at Austin; Carnegie Mellon, 2023–

ERNEST SCHIMMERLING, Professor – Ph.D., University of California at Los Angeles; Carnegie Mellon, 1998–

DEJAN SLEPČEV, Professor & Associate Department Head – Ph.D., University of Texas at Austin; Carnegie Mellon, 2006–

RICHARD STATMAN, Professor – Ph.D., Stanford University; Carnegie Mellon, 1984–

PRASAD TETALI, Alexander M. Knaster Professor & Department Head - Ph.D., New York University; Carnegie Mellon, 2021-

IAN TICE, Associate Professor - Ph.D., New York University; Carnegie Mellon, 2012-

KONSTANTIN TIKHOMIROV, Associate Professor - Ph.D., University of Alberta; Carnegie Mellon, 2022-

TOMASZ TKOCZ, Associate Professor - Ph.D., University of Warwick; Carnegie Mellon, 2017-

NOEL WALKINGTON, Professor - Ph.D., University of Texas at Austin; Carnegie Mellon, 1989-

ANTHONY WESTON, Associate Teaching Professor - Ph.D., Kent State University; Carnegie Mellon, 2022-

JOHANNES WIESEL, Assistant Professor - DPhil, University of Oxford; Carnegie Mellon, 2023-

ZELEALEM YILMA, Associate Teaching Professor - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2015-

MICHAEL YOUNG, Associate Professor & Associate Dean for Diversity, Equity and Inclusion - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021-

Emeriti Faculty

PETER ANDREWS, Professor Emeritus - Ph.D., Princeton University; Carnegie Mellon, 1963-

MANUEL BLUM, University Professor Emeritus - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1999-

DEBORAH BRANDON, Associate Teaching Professor Emeritus - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1991-

GÉRARD CORNUÉJOLS, IBM University Professor of Operations Research Emeritus - Ph.D., Cornell University; Carnegie Mellon, 1978-

JOHN LEHOCZKY, Thomas Lord University Professor of Statistics Emeritus - Ph.D., Stanford University; Carnegie Mellon, 1969-

ROY NICOLAIDES, Professor Emeritus - Ph.D., University of London; Carnegie Mellon, 1984-

DAVID OWEN, Professor Emeritus - Ph.D., Brown University; Carnegie Mellon, 1967-

ROBERT PEGO, Professor Emeritus - Ph.D., University of California at Berkeley; Carnegie Mellon, 2004-

JACK SCHAEFFER, Professor Emeritus - Ph.D., Indiana University; Carnegie Mellon, 1983-

ROBERT SEKERKA, University Professor Emeritus - Ph.D., Harvard University; Carnegie Mellon, 1969-

STEVEN SHREVE, University Professor Emeritus - Ph.D., University of Illinois; Carnegie Mellon, 1980-

SHLOMO TA'ASAN, Professor Emeritus - Ph.D., Weizmann Institute; Carnegie Mellon, 1994-

LUC TARTAR, University Professor of Mathematics Emeritus - Ph.D., University of Paris; Carnegie Mellon, 1987-

RUSSELL WALKER, Teaching Professor Emeritus - D.A., Carnegie Mellon University; Carnegie Mellon, 1984-

WILLIAM WILLIAMS, Professor Emeritus - Ph.D., Brown University; Carnegie Mellon, 1966-

Department of Mathematical Sciences Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

21-101 Freshman Mathematics Seminar

Intermittent: 3 units

This course is offered in the Fall semester for first semester Freshmen interested in majoring in mathematics. Topics vary from year to year. Recent topics have included Fermat's last theorem, finite difference equations, convexity, and fractals. (Three 50 minute lectures)

21-102 Exploring Modern Mathematics

Fall and Spring: 9 units

This course is designed for non-math majors who are interested in learning some contemporary applications of mathematics with minimal prerequisite math knowledge. The course will survey the mathematical concepts centered along various themes, which may include the mathematics of social choice (voting and apportionment systems), topics in management science (optimization and elementary graph theory), modeling growth systems (population and finance), shape and form (symmetry and fractals), basic applications of probability and counting, and basic applications of number theory (cryptography and coding theory). Additional topics may be presented at the discretion of the instructor.

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-108 Introduction to Mathematical Concepts

Fall and Spring: 6 units

This course is an introduction to the vocabulary necessary for understanding and proving mathematical statements. The topics in this course include integers, rational numbers, polynomials, divisibility of numbers and polynomials, basic logic, sets, relations, functions, rule of sum, and rule of product. (Three 50 minute lectures, two 50 minute recitations)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-111 Calculus I

Fall and Spring: 10 units

Review of basic algebra, functions, limits, derivatives of algebraic, exponential and logarithmic functions, curve sketching, maximum-minimum problems. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. (Three 50 minute lectures, two 50 minute recitations)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-112 Calculus II

Fall and Spring: 10 units

Definite and indefinite integrals, and hyperbolic functions; applications of integration, integration by substitution and by parts. Successful completion of 21-111 and 21-112 entitles a student to enroll in any mathematics course for which 21-120 is a prerequisite. (Three 50 minute lectures, two 50 minute recitations)

Prerequisite: 21-111

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-120 Differential and Integral Calculus

All Semesters: 10 units

Functions, limits, derivatives, logarithmic, exponential, and trigonometric functions, inverse functions; L'Hospital's Rule, curve sketching, Mean Value Theorem, related rates, linear and approximations, maximum-minimum problems, inverse functions, definite and indefinite integrals; integration by substitution and by parts. Applications of integration, as time permits. (Three 50 minute lectures, two 50 minute recitations)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-122 Integration and Approximation

All Semesters: 10 units

Integration by trigonometric substitution and partial fractions; arclength; improper integrals; Simpson's and Trapezoidal Rules for numerical integration; separable differential equations, Newton's method, Euler's method, Taylor's Theorem, including a discussion of the remainder, sequences, series, power series. Parametric curves, polar coordinates, vectors, dot product. (Three 50 minute lectures, two 50 minute recitations)

Prerequisites: 21-112 or 21-120

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-124 Calculus II for Biologists and Chemists

Spring: 10 units

This is intended as a second calculus course for biology and chemistry majors. It uses a variety of computational techniques based around the use of MATLAB or a similar system. Topics to be covered include: Integration: techniques and numerical integration. Ordinary differential equations: techniques for solving ODEs and numerical methods. Modeling with ODEs (e.g., infection, population models). Linear algebra: matrices, complex numbers, eigenvalues, eigenvectors. Systems of ordinary differential equations (if time allows: stability of differential systems). Probability: discrete and continuum probability, conditional probability and independence, limit theorems, important distributions, probabilistic models. (Three 50 minute lectures, two 50 minute recitations)

Prerequisites: 21-120 or 21-112

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-127 Concepts of Mathematics

All Semesters: 12 units

This course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus is on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. (Three 50 minute lectures, two 50 minute recitations)

Prerequisites: 21-112 Min. grade C or 21-120 Min. grade C or 21-108 Min. grade C or 15-112 Min. grade C

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-128 Mathematical Concepts and Proofs

Fall: 12 units

This course is intended for MCS first-semester students who are interested in pursuing a major in mathematical sciences. The course introduces the basic concepts, ideas and tools involved in doing mathematics. As such, its main focus is on presenting informal logic, and the methods of mathematical proof. These subjects are closely related to the application of mathematics in many areas, particularly computer science. Topics discussed include a basic introduction to elementary number theory, induction, the algebra of sets, relations, equivalence relations, congruences, partitions, and functions, including injections, surjections, and bijections. A basic introduction to the real numbers, rational and irrational numbers. Supremum and infimum of a set. (Three 50 minute lectures, two 50 minute recitations)

Prerequisites: 21-108 Min. grade C or 15-112 Min. grade C or 21-120 Min. grade C or 21-112 Min. grade C

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-150 Mathematics and the Arts

Intermittent: 9 units

Mathematics and the creative arts have long, interlinked histories. This course touches upon a broad range of mathematical ideas and the writers, artists, and art movements that were influenced and inspired by them. Topics include the use of geometric patterns in Islamic art, the influence of non-Euclidean geometry on Cubism, the constrained writing experiments of the Oulipo, and literary works exploring the concept of infinity.

21-201 Undergraduate Colloquium

Fall and Spring: 1 unit

The purpose of this course is to introduce math majors to the different degree programs in Mathematical Sciences, and to inform math majors about relevant topics such as advising, math courses, graduate schools, and typical career paths in the mathematical sciences. The Career and Professional Development Center will present modules on professional communication, developing interview and networking skills, and preparing for career fairs. (One 50 minute session)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-228 Discrete Mathematics

Fall and Spring: 9 units

The techniques of discrete mathematics arise in every application of mathematics, which is not purely continuous, for example in computer science, economics, and general problems of optimization. This course introduces two of the fundamental areas of discrete mathematics: enumeration and graph theory. The introduction to enumeration includes permutations, combinations, and topics such as discrete probability, combinatorial distributions, recurrence relations, generating functions, Ramsey's Theorem, and the principle of inclusion and exclusion. The introduction to graph theory includes topics such as paths, walks, connectivity, Eulerian and Hamilton cycles, planar graphs, Euler's Theorem, graph coloring, matchings, networks, and trees. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-127 or 15-151 or 21-128

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-235 Mathematical Studies Analysis I

Fall: 12 units

A component of the honors program, 21-235 is a more demanding version of 21-355 of greater scope. Topics to be covered typically include: metric spaces, normed spaces, and inner product spaces; further properties of metric spaces such as completeness, density, compactness, and connectedness; limits and continuity of maps between metric spaces, homeomorphisms, extension theorems, contraction mappings, extreme and intermediate value theorems; convergence of sequences and series of functions; metric spaces of functions, sequences, and metric subsets; Stone-Weierstrass and Arzela-Ascoli theorems; Baire category and applications; infinite series in normed spaces, convergence tests, and power series; differential calculus of maps between normed spaces, inverse and implicit function theorems in Banach spaces; existence results in ordinary differential equations. The prerequisite sequence 21-128, 21-242, 21-269 is particularly recommended. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-259 or 21-269 or 21-268 or 21-256

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-236 Mathematical Studies Analysis II

Spring: 12 units

A component of the honors program, 21-236 is a more demanding version of 21-356 of greater scope. Topics to be covered typically include: Lebesgue measure in Euclidean space, measurable functions, the Lebesgue integral, integral limit theorems, Fubini-Tonelli theorem, and change of variables; Lebesgue spaces, completeness, approximation, and embeddings; absolutely continuous functions, functions of bounded variation, and curve lengths; differentiable submanifolds of Euclidean space, tangent spaces, mappings between manifolds, vector and tensor fields, manifolds with boundary and orientations; differential forms, integration of forms, Stokes' theorem; Hausdorff measure, divergence theorem. (Three 50 minute lectures, one 50 minute recitation)

Prerequisite: 21-235 Min. grade B

21-237 Mathematical Studies Algebra I

Fall: 12 units

A component of the honors program, 21-237 is a more demanding version of 21-373 (Algebraic Structures) of greater scope. Abstract algebra is the study of algebraic systems by the axiomatic method, and it is one of the core areas of modern mathematics. This course is a rigorous and fast-paced introduction to the basic objects in abstract algebra, focusing on groups and rings. Group-theoretic topics to be covered include: homomorphisms, subgroups, cosets, Lagrange's theorem, conjugation, normal subgroups, quotient groups, isomorphism theorems, automorphism groups, characteristic subgroups, group actions, Cauchy's theorem, Sylow's theorem, normalisers, centralisers, class equation, finite p-groups, permutation and alternating groups, direct and semidirect products, simple groups, subnormal series, the Jordan-Holder theorem. Ring-theoretic topics include: subrings, ideals, quotient rings, isomorphism theorems, polynomial rings, Zorn's Lemma, prime and maximal ideals, prime and irreducible elements, factorization, PIDs and UFDs, Noetherian domains, the Hilbert Basis Theorem, Gauss' lemma and the Eisenstein criterion for irreducibility, fields of fractions, properties of polynomial rings over fields and UFDs, finite fields and applications. The prerequisite sequence of 21-128, 21-242, 21-269 is particularly recommended. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: (15-151 or 21-127 or 21-128) and (21-269 or 21-268) and (21-242 or 21-241)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-238 Mathematical Studies Algebra II

Spring: 12 units

A component of the honors program, 21-238 is a more demanding version of 21-341 (Linear Algebra) of greater scope. Linear algebra is a crucial tool in pure and applied mathematics. This course aims to introduce the main ideas at a high level of rigour and generality. The course covers vector spaces over arbitrary fields and the natural generalization to modules over rings. Vector space topics to be covered include: fields, Zorn's Lemma, vector spaces (possibly infinite dimensional) over an arbitrary field, independent sets, bases, existence of a basis, exchange lemma, dimension. Linear transformations, dual space, multilinear maps, tensor products, exterior powers, the determinant, eigenvalues, eigenvectors, characteristic and minimal polynomial of a transformation, the Cayley-Hamilton theorem. Module-theoretic topics to be covered include: review of (commutative) rings, R-modules, sums and quotients of modules, free modules, the structure theorem for finitely generated modules over a PID, Jordan and rational canonical forms, structure theory of finitely generated abelian groups. Further topics in real and complex inner product spaces include: orthonormal sets, orthonormal bases, the Gram-Schmidt process, symmetric/Hermitian operators, orthogonal/unitary operators, the spectral theorem, quadratic forms, the singular value decomposition. Possible additional topics: applications to combinatorics, category theory, representations of finite groups, unitary representations of infinite groups. (Three 50 minute lectures, one 50 minute recitation)

Prerequisite: 21-237 Min. grade B

21-240 Matrix Algebra with Applications

Fall and Spring: 10 units

Vectors and matrices, the solution of linear systems of equations, vector spaces and subspaces, orthogonality, determinants, real and complex eigenvalues and eigenvectors, linear transformations. The course is intended for students in Economics, Statistics, Information Systems, and it will focus on topics relevant to these fields. (Three 50 minute lectures, one 50 minute recitation)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-241 Matrices and Linear Transformations

All Semesters: 11 units

A first course in linear algebra intended for scientists, engineers, mathematicians and computer scientists. Students will be required to write some straightforward proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, row space and column space of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices. (Three 50 minute lectures, two 50 minute recitations)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-242 Matrix Theory

Fall: 11 units

A component of the honors program, 21-242 is a more demanding version of 21-241 (Matrix Algebra and Linear Transformations), of greater scope, with increased emphasis placed on rigorous proofs. Topics to be covered: complex numbers, real and complex vectors and matrices, row space and column space of a matrix, rank and nullity, solving linear systems by row reduction of a matrix, inverse matrices and determinants, change of basis, linear transformations, inner product of vectors, orthonormal bases and the Gram-Schmidt process, eigenvectors and eigenvalues, diagonalization of a matrix, symmetric and orthogonal matrices, hermitian and unitary matrices, quadratic forms. (Three 50 minute lectures, two 50 minute recitations)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-254 Linear Algebra and Vector Calculus for Engineers

Fall and Spring: 11 units

This course will introduce the fundamentals of vector calculus and linear algebra. The topics include vector and matrix operations, determinants, linear systems, matrix eigenvalue problems, vector differential calculus including gradient, divergence, curl, and vector integral calculus including line, surface, and volume integral theorems. Lecture and assignments will emphasize the applications of these topics to engineering problems. (Three 50 minute lectures, one 50 minute recitation)

Prerequisite: 21-122

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-256 Multivariate Analysis

Fall and Spring: 9 units

This course is designed for students in Economics or Business Administration. Matrix algebra: vectors, matrices, systems of equations, dot product, cross product, lines and planes. Optimization: partial derivatives, the chain rule, gradient, unconstrained optimization, constrained optimization (Lagrange multipliers and the Kuhn-Tucker Theorem). Improper integrals. Multiple integration: iterated integrals, probability applications, triple integrals, change of variables. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-120 or 21-112

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-257 Models and Methods for Optimization

Intermittent: 9 units

Introduces basic methods of operations research and is intended primarily for Business Administration and Economics majors. Review of linear systems; linear programming, including the simplex algorithm, duality, and sensitivity analysis; the transportation problem; the critical path method; the knapsack problem, traveling salesman problem, and an introduction to set covering models. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 18-202 or 21-256 or 21-242 or 21-241 or 06-262 or 21-240

21-259 Calculus in Three Dimensions

All Semesters: 10 units

Vectors, lines, planes, quadratic surfaces, polar, cylindrical and spherical coordinates, partial derivatives, directional derivatives, gradient, divergence, curl, chain rule, maximum-minimum problems, multiple integrals, parametric surfaces and curves, line integrals, surface integrals, Green-Gauss theorems. (Three 50 minute lectures, two 50 minute recitations)

Prerequisite: 21-122

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-260 Differential Equations

All Semesters: 9 units

Ordinary differential equations: first and second order equations, applications, Laplace transforms; partial differential equations: partial derivatives, separation of variables, Fourier series; systems of ordinary differential equations; applications. 21-259 or 21-268 or 21-269 are recommended. (Three 50 minute lectures, one 50 minute recitation)

Prerequisite: 21-122

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-261 Introduction to Ordinary Differential Equations

Spring: 10 units

A first course in ordinary differential equations intended primarily for math majors and for those students interested in a more conceptual treatment of the subject. One of the goals of this course is to prepare students for upper level courses on differential equations, mathematical analysis and applied mathematics. Students will be required to write rigorous arguments. Topics to be covered: Ordinary differential equations: first and second order equations, applications, Laplace transform, systems of linear ordinary differential equations; systems of nonlinear ordinary differential equations, equilibria and stability, applications. Corequisites: (21-268 or 21-269 or 21-259) and (21-241 or 21-242). (Three 50 minute lectures, one 50 minute recitation)

Prerequisite: 21-122

21-266 Vector Calculus for Computer Scientists

Spring: 10 units

This course is an introduction to vector calculus making use of techniques from linear algebra. Topics covered include scalar-valued and vector-valued functions, conic sections and quadric surfaces, new coordinate systems, partial derivatives, tangent planes, the Jacobian matrix, the chain rule, gradient, divergence, curl, the Hessian matrix, linear and quadratic approximation, local and global extrema, Lagrange multipliers, multiple integration, parametrised curves, line integrals, conservative vector fields, parametrised surfaces, surface integrals, Green's theorem, Stokes's theorem and Gauss's theorem. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-122 and (21-241 or 21-242)

21-268 Multidimensional Calculus

Fall and Spring: 11 units

A serious introduction to multidimensional calculus that makes use of matrices and linear transformations. Results will be stated carefully and rigorously. Students will be expected to write some proofs; however, some of the deeper results will be presented without proofs. Topics to be covered include functions of several variables, limits, and continuity, partial derivatives, differentiability, chain rule, inverse and implicit functions, higher derivatives, Taylor's theorem, optimization, multiple integrals and change of variables, line integrals, surface integrals, divergence theorem and Stokes's theorem. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-122 and (21-241 or 21-242)

21-269 Vector Analysis

Spring: 10 units

A component of the honors program, 21-269 is a more demanding version of 21-268 of greater scope, with greater emphasis placed on rigorous proofs. Topics to be covered typically include: the real field, sups, infs, and completeness; geometry and topology of metric spaces; limits, continuity, and derivatives of maps between normed spaces; inverse and implicit function theorems, higher derivatives, Taylor's theorem, extremal calculus, and Lagrange multipliers. Integration. Iterated integration and change of variables. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-241 Min. grade A or 21-242 Min. grade B

21-270 Introduction to Mathematical Finance

Spring: 9 units

This is a first course for those considering majoring or minoring in Computational Finance. The theme of this course is pricing derivative securities by replication. The simplest case of this idea, static hedging, is used to discuss net present value of a non-random cash flow, internal rate of return, and put-call option parity. Pricing by replication is then considered in a one-period random model. Risk-neutral probability measures, the Fundamental Theorems of Asset Pricing, and an introduction to expected utility maximization and mean-variance analysis are presented in this model. Finally, replication is studied in a multi-period binomial model. Within this model, the replicating strategies for European and American options are determined. (Three 50 minute lectures)

Prerequisites: 21-112 or 21-120

21-292 Operations Research I

Spring: 9 units

Operations research offers a scientific approach to decision making, most commonly involving the allocation of scarce resources. This course develops some of the fundamental methods used. Linear programming: the simplex method and its linear algebra foundations, duality, post-optimality and sensitivity analysis; the transportation problem; the critical path method; non-linear programming methods. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-122 and (21-240 or 21-241 or 21-242) and (15-251 or 21-228)

21-295 Putnam Seminar

Fall: 3 units

A problem solving seminar designed to prepare students to participate in the annual William Lowell Putnam Mathematical Competition. Students solve and present their solutions to problems posed. (One 50 minute session)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-300 Basic Logic**

Fall: 9 units

Propositional and predicate logic: Syntax, proof theory and semantics up to completeness theorem, Lowenheim Skolem theorems, and applications of the compactness theorem. (Three 50 minute lectures)

Prerequisites: 21-373 or 15-251 or 21-228

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-301 Combinatorics**

Fall and Spring: 9 units

A major part of the course concentrates on algebraic methods, which are relevant in the study of error correcting codes, and other areas. Topics covered in depth include permutations and combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, and the Fibonacci sequence and the harmonic series. Additional topics may include existence proofs, partitions, finite calculus, generating combinatorial objects, Polya theory, codes, probabilistic methods. (Three 50 minute lectures)

Prerequisites: 21-122 and (21-228 or 15-251)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-302 Lambda Calculus**

Intermittent: 9 units

An introductory course in classical lambda calculus, with an emphasis on syntax. The course will describe many research problems which are suitable topics for senior theses or master's theses. Topics will include: Basic properties of reduction and conversion; Reduction and conversion strategies; Calculability and representation of data types; Elementary theory of Ershov numberings; Bohm's theorem, easy terms, and other exotic combinations; Solvability of functional equations (unification); Combinatorics and bases; Simple and algebraic types; Labelled reduction and intersection types; Extensionality and the omega rule.

Prerequisites: 21-300 or 80-310 or 15-150

21-321 Interactive Theorem Proving

Fall: 9 units

Computational proof assistants now make it possible to work interactively to write mechanically verified definitions, theorems, and proofs. Important theorems have been formalized in this way, and digital libraries are being developed collaboratively by the mathematical community. Formalization of mathematics also serves as a gateway to the use of new technologies for discovery, such as automated reasoning and machine learning. This course will teach you how to formalize mathematics so that you, too, can contribute to the effort. We will explore a logical framework, dependent type theory, which serves as a practical foundation in a number of proof assistants. Finally, as time allows, we will explore ways of automating various aspects of mathematical reasoning. (Three 50 minute lectures)

Prerequisites: 15-151 or 21-127 or 21-128

21-322 Topics in Formal Mathematics

Intermittent: 9 units

Complementary to 21-321 Interactive Theorem Proving, this course is designed to present special topics on the use of formalization and formal methods in mathematics. For example, the course might focus on formalization of a specific branch of mathematics, or on a specific method for automation or computational reasoning.

Prerequisites: (15-151 or 21-127 or 21-128) and (21-235 or 21-355) and (21-268 or 21-266 or 21-259 or 21-269)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-325 Probability**

Fall and Spring: 9 units

This course focuses on the understanding of basic concepts in probability theory and illustrates how these concepts can be applied to develop and analyze a variety of models arising in computational biology, finance, engineering and computer science. The firm grounding in the fundamentals is aimed at providing students the flexibility to build and analyze models from diverse applications as well as preparing the interested student for advanced work in these areas. The course will cover core concepts such as probability spaces, random variables, random vectors, multivariate densities, distributions, expectations, sampling and simulation; independence, conditioning, conditional distributions and expectations; limit theorems such as the strong law of large numbers and the central limit theorem; as well as additional topics such as large deviations, random walks and Markov chains, as time permits. (Three 50 minute lectures)

Prerequisites: 21-268 or 21-259 or 21-269 or 21-256

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-329 Set Theory**

Spring: 9 units

Set theory was invented about 110 years ago by George Cantor as an instrument to understand infinite objects and to compare different sizes of infinite sets. Since then set theory has come to play an important role in several branches of modern mathematics, and serves as a foundation of mathematics. Contents: Basic properties of natural numbers, countable and uncountable sets, construction of the real numbers, some basic facts about the topology of the real line, cardinal numbers and cardinal arithmetic, the continuum hypothesis, well ordered sets, ordinal numbers and transfinite induction, the axiom of choice, Zorn's lemma. Optional topics if time permits: Infinitary combinatorics, filters and large cardinals, Borel and analytic sets of reals. (Three 50 minute lectures)

Prerequisites: 21-127 or 15-151 or 21-128

21-341 Linear Algebra

Fall and Spring: 9 units

A mathematically rigorous treatment of Linear Algebra over an arbitrary field. Topics studied will include abstract vector spaces, linear transformations, determinants, eigenvalues, eigenvectors, inner products, invariant subspaces, canonical forms, the spectral theorem and the singular value decomposition. 21-373 recommended. (Three 50 minute lectures)

Prerequisites: (21-241 or 21-242) and 21-373

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-344 Numerical Linear Algebra**

Spring: 9 units

An introduction to algorithms pertaining to matrices and large linear systems of equations. Direct methods for large sparse problems including graph data structures, maximum matchings, row and column orderings, and pivoting strategies. Iterative methods including Conjugate Gradient and GMRES, with a discussion of preconditioning strategies. Additional topics include: computation of eigenvalues and eigenvectors, condition numbers, the QR and singular value decompositions, least-squares systems. (Three 50 minute lectures)

Prerequisites: 15-112 and (21-240 or 21-242 or 21-241) and (21-259 or 21-268 or 21-269)

21-355 Principles of Real Analysis I

Fall and Spring: 9 units

This course provides a rigorous and proof-based treatment of functions of one real variable. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. Topics include: The Real Number System: Field and order axioms, sups and infs, completeness. Real Sequences. Bolzano-Weierstrass theorem. Topology of the Real Line: Open sets, closed sets, compactness, Heine-Borel Theorem. Continuity: extreme and intermediate value theorems, uniform continuity. Differentiation: chain rule, local extrema, mean-value theorem, L'Hospital's rule, Taylor's theorem. Riemann integration: sufficient conditions for integrability, fundamental theorems of calculus. (Three 50 minute lectures)

Prerequisites: (21-128 or 15-151 or 21-127) and 21-122
Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-356 Principles of Real Analysis II

Fall and Spring: 9 units

This course provides a rigorous and proof-based treatment of functions of several real variables. The course presumes some mathematical sophistication including the ability to recognize, read, and write proofs. Topics include: Metric spaces. Differential calculus in Euclidean spaces: continuity, differentiability, partial derivatives, gradients, differentiation rules, implicit and inverse function theorems. Multiple integrals. Integration on curves and hypersurfaces: arclength, and generalized area. The divergence theorem and the 3D Stokes theorem. Regarding prerequisites, 21-268 or 21-269 are strongly recommended rather than 21-259. (Three 50 minute lectures)

Prerequisites: (21-269 or 21-259 or 21-268) and (21-241 or 21-242) and 21-355

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-360 Differential Geometry of Curves and Surfaces

Intermittent: 9 units

The course is a rigorous introduction to the differential and integral calculus of curves and surfaces. Topics to be covered include: Parameterized and regular curves Frenet equations canonical coordinate system, local canonical forms, global properties of plane curves Regular surfaces, differential functions on surfaces, the tangent plane and differential of a map, orientation of surfaces, characterization of compact orientable surfaces, classification of compact surfaces The geometry of the Gauss map, isometries and conformal maps, parallel transport, geodesics, the Gauss-Bonnet theorem and applications. More topics may be covered, as time allows. Students should be prepared to write proofs and perform computations. 21-356 or 21-236 are recommended. (Three 50 minute lectures)

Prerequisites: 21-269 or 21-268

21-365 Projects in Applied Mathematics

Intermittent: 9 units

This course provides students with an opportunity to solve problems posed by area companies. It is also designed to provide experience working as part of a team to solve problems for a client. The background needed might include linear programming, simulation, data analysis, scheduling, numerical techniques, etc.

21-366 Topics in Applied Mathematics

Intermittent: 9 units

Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different.

Course Website: <https://www.cmu.edu/math/courses/special-topics.html>

21-369 Numerical Methods

Fall and Spring: 12 units

This course provides an introduction to the use of computers to solve scientific problems. Methods for the computational solution of linear algebra systems, nonlinear equations, the interpolation and approximation of functions, differentiation and integration, and ordinary differential equations. Analysis of roundoff and discretization errors and programming techniques. 21-268 or 21-269 are recommended prerequisites, rather than 21-259. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: (15-112 or 15-110) and (21-268 or 21-259 or 21-269) and (21-241 or 21-240 or 21-242 or 33-232) and (21-630 or 21-260 or 21-261 or 33-231)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-370 Discrete Time Finance

Fall: 9 units

This course introduces the Black-Scholes option pricing formula, shows how the binomial model provides a discretization of this formula, and uses this connection to fit the binomial model to data. It then sets the stage for Continuous-Time Finance by discussing in the binomial model the mathematical technology of filtrations, martingales, Markov processes and risk-neutral measures. Additional topics are American options, expected utility maximization, the Fundamental Theorems of Asset Pricing in a multi-period setting, and term structure modeling, including the Heath-Jarrow-Morton model. Students in 21-370 are expected to read and write proofs. Acceptable corequisites include 21-325 or 36-225 (Three 50 minute lectures)

Prerequisites: (70-492 or 21-270) and (21-256 or 21-259 or 21-268 or 21-269)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-371 Functions of a Complex Variable

Fall: 9 units

This course provides an introduction to one of the basic topics of both pure and applied mathematics and is suitable for those with both practical and theoretical interests. Algebra and geometry of complex numbers; complex differentiation and integration. Cauchy's theorem and applications; conformal mapping; applications. 21-268 or 21-269 are recommended prerequisites, rather than 21-259. (Three 50 minute lectures)

Prerequisites: 21-355 or 21-235

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-373 Algebraic Structures

Fall and Spring: 9 units

Groups: Homomorphisms. Subgroups, cosets, Lagrange's theorem. Conjugation. Normal subgroups, quotient groups, first isomorphism theorem. Group actions, Cauchy's Theorem. Dihedral and alternating groups. The second and third isomorphism theorems. Rings: Subrings, ideals, quotient rings, first isomorphism theorem. Polynomial rings. Prime and maximal ideals, prime and irreducible elements. PIDs and UFDs. Noetherian domains. Gauss' lemma. Eisenstein criterion. Fields: Field of fractions of an integral domain. Finite fields. Applications to coding theory, cryptography, number theory. (Three 50 minute lectures)

Prerequisites: (15-151 or 21-128 or 21-127) and (21-242 or 21-241)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>

21-374 Field Theory

Spring: 9 units

The purpose of this course is to provide a successor to Algebraic Structures, with an emphasis on applications of groups and rings within algebra to some major classical problems. These include constructions with a ruler and compass, and the solvability or unsolvability of equations by radicals. It also offers an opportunity to see group theory and basic ring theory "in action", and introduces several powerful number theoretic techniques. The basic ideas and methods required to study finite fields will also be introduced. These ideas have recently been applied in a number of areas of theoretical computer science including primality testing and cryptography. (Three 50 minute lectures)

Prerequisite: 21-373

21-375 Topics in Algebra

Intermittent: 9 units

Typical of courses that might be offered from time to time are elliptic curves, commutative algebra, and theory of Boolean functions. (Three 50 minute lectures)

Prerequisite: 21-373

21-377 Monte Carlo Simulation for Finance

Intermittent: 9 units

first course in Monte Carlo simulation, with applications to Mathematical Finance. Students will put into practice many of the theoretical ideas introduced in Continuous Time Finance. Topics to be covered: random variable/stochastic process generation; options pricing; variance reduction; Markov chain Monte Carlo Methods.

Prerequisites: 21-420 or 21-325 Min. grade B

21-378 Mathematics of Fixed Income Markets

Fall: 9 units

A first course in fixed income. Students will be introduced to the most common securities traded in fixed income markets and the valuation methods used to price them. Topics covered include discount factors; interest rates basics; pricing of coupon bonds; identifying the yield to maturity, as well as bond sensitivities to interest rates; term structure modeling; forward and swap rates; fixed income derivatives (including mortgage backed securities) and their valuation through backwards induction; fixed income indexes and return attribution. For a co-requisite, 36-225 can be accepted as an alternative for 21-325. (Three 50 minute lectures)

Prerequisite: 21-270 Min. grade B

21-380 Introduction to Mathematical Modeling

Intermittent: 9 units

This course shall examine mathematical models, which may be used to describe natural phenomena. Examples, which have been studied include: continuum description of highway traffic, discrete velocity models of a monotonic gas, chemotactic behavior in biological systems, European options pricing, and cellular-automata. Systems such as the first four are described by partial differential equations; the last involves discrete-time and discrete-phase dynamical systems, which have been used to successfully represent both physical and biological systems. The course will develop these models and then examine the behavior of the underlying systems, both analytically and numerically. The mathematical tools required will be developed in the course. (Three 50 minute lectures)

Prerequisites: (21-242 or 21-241) and (21-260 or 21-261)

21-387 Monte Carlo Methods and Applications

Intermittent: 9 units

The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language. (Two 80 minute lectures)

Prerequisites: (21-259 Min. grade C or 21-269 Min. grade C or 21-268 Min. grade C or 21-266 Min. grade C) and (18-465 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 36-235 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C or 15-259 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~kmc Crane/random/>**21-393 Operations Research II**

Fall: 9 units

Building on an understanding of Linear Programming developed in 21-292 Operations Research I, this course introduces more advanced topics. Integer programming, including cutting planes and branch and bound. Dynamic programming. An introduction to Combinatorial Optimization including optimal spanning trees, shortest paths, the assignment problem and max-flow/min-cut. The traveling salesman problem and NP-completeness. An important goal of this course is for the student to gain experience with the process of working in a group to apply operations research methods to solve a problem. A portion of the course is devoted to a group project based upon case studies and the methods presented. 36-410 recommended. (Three 50 minute lectures)

Prerequisites: (15-251 or 21-228) and 21-292

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-400 Intermediate Logic**

Intermittent: 9 units

The course builds on the proof theory and model theory of first-order logic covered in 21-300. These are applied in 21-400 to Peano Arithmetic and its standard model, the natural numbers. The main results are the incompleteness, undefinability and undecidability theorems of Godel, Tarski, Church and others. Leading up to these, it is explained how logic is formalized within arithmetic, how this leads to the phenomenon of self-reference, and what it means for the axioms of a theory to be computably enumerable. Related aspects of computability theory are included to the extent that time permits. (Three 50 minute lectures)

Prerequisite: 21-300

21-410 Research Topics in Mathematical Sciences

All Semesters: 9 units

This course affords undergraduates to pursue elementary research topics in the area of expertise of the instructor. The prerequisites will depend on the content of the course. (Three 50 minute lectures)

Course Website: <https://www.cmu.edu/math/courses/special-topics.html>**21-420 Continuous-Time Finance**

Spring: 9 units

This course begins with Brownian motion, stochastic integration, and Ito's formula from stochastic calculus. This theory is used to develop the Black-Scholes option pricing formula and the Black-Scholes partial differential equation. Additional topics may include models of credit risk, simulation, and expected utility maximization. (Three 50 minute lectures)

Prerequisites: (21-260 or 18-202) and 21-370 and (36-225 or 36-217 or 15-259 or 36-218 or 21-325)

21-435 Applied Harmonic Analysis

Intermittent: 9 units

This course serves as a broad introduction to harmonic analysis and its applications, particularly in 1-dimensional signal processing and in image processing, for undergraduate students in mathematics, engineering, and the applied sciences. Topics include: Discrete Fourier transform and fast Fourier transform; Fourier series and the Fourier transform; Hilbert spaces and applications; Shannon sampling theorem, bandlimited functions, uncertainty principle; Wavelets and multi-resolution analysis; Applications in image processing. (Three 50 minute lectures)

Prerequisites: (21-355 or 21-235) and (21-242 or 21-241)

21-441 Number Theory

Fall: 9 units

Number theory deals with the integers, the most basic structures of mathematics. It is one of the most ancient, beautiful, and well-studied branches of mathematics, and has recently found surprising new applications in communications and cryptography. Course contents: Structure of the integers, greatest common divisors, prime factorization. Modular arithmetic, Fermat's Theorem, Chinese Remainder Theorem. Number theoretic functions, e.g. Euler's function, Mobius functions, and identities. Diophantine equations, Pell's Equation, continued fractions. Modular polynomial equations, quadratic reciprocity. (Three 50 minute lectures)

Prerequisites: (21-242 or 21-241) and 21-373

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-455 Intermediate Real Analysis I**

Fall: 12 units

This course provides a rigorous and proof-based treatment of the general theory of functions on metric spaces. The course serves as a more advanced version of 21-355 Principles of Real Analysis and is primarily intended for students who have taken 21-269. Topics include: Metric spaces: Completeness, density, separability, compactness, connectedness. Baire theorem and applications. Contraction maps: fixed points, applications, inverse, and implicit function theorems. Spaces of functions: uniform and pointwise convergence, Stone-Weierstrass theorem, Arzela-Ascoli theorem. (Three 50 minute lectures, one 50 minute recitation)

Prerequisites: 21-269 or 21-268

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-456 Intermediate Real Analysis II**

Spring: 10 units

This course provides a rigorous and proof-based treatment of the general theory of functions on Euclidean spaces. The course serves as a more advanced version of 21-356 Principles of Real Analysis II and is primarily intended for students who have taken 21-455. Topics include: Lebesgue integration in Euclidean spaces: Lebesgue measure and Lebesgue integration, convergence and integration theorems, Fubini's theorem, change of variables. Curves, arclength, curve integrals. Submanifolds of Euclidean space: applications of the inverse and implicit function theorems, tangent space, normal space, orientation, integration on manifolds. Theorems of vector calculus: divergence theorem, Stokes theorem in 3D. (Three 50 minute lectures, one 50 minute recitations)

Prerequisites: 21-235 or 21-355 or 21-455

21-465 Topology

Intermittent: 9 units

Metric spaces. Topological spaces. Separation axioms. Open, closed and compact sets. Continuous functions. Product spaces, subspaces, quotient spaces. Connectedness and path-connectedness. Homotopy. Fundamental group of a pointed space. Simply connected spaces. Winding number, the fundamental group of the circle. Functorial property of the fundamental group. Brouwer fixed point theorem. Covering spaces. van Kampen's theorem. 2-manifolds. Triangulations. Euler characteristic. Surgery, classification of compact 2-manifolds. (Three 50 minute lectures)

Prerequisites: 21-373 and 21-355

21-469 Computational Introduction to Partial Differential Equations

Intermittent: 12 units

A Partial Differential Equation (PDE for short) is a differential equation involving derivatives with respect to more than one variable. These arise in numerous applications from various disciplines. Most PDEs do not have explicit solutions, and hence computational methods are essential for understanding the underlying phenomena. This course will serve as a first introduction to PDEs and their numerical approximation, and will focus on a variety of mathematical models. It will cover both analytical methods, numerical methods (e.g. finite differences) and the use of a computer to approximate and visualize solutions. The mathematical ideas behind phenomena observed in nature will be studied at the theoretical level and in numerical simulations (e.g. speed of wave propagation, and/or shocks in traffic flow). Topics will include: Derivation of PDEs from physical principles, analytical and computational tools for the transport equation and the Poisson equation, Fourier analysis, analytical and numerical techniques for the solution of parabolic equations and if time permits, the wave equation. (Three 50 minute lectures, one 80 minute recitation)

Prerequisites: (21-240 or 21-241 or 21-242) and (21-259 or 21-268 or 21-269) and (21-261 or 33-231 or 21-260 or 21-630) and (15-112 or 15-110)

Course Website: <https://www.cmu.edu/math/undergrad/math-course-information.html>**21-470 Selected Topics in Analysis**

Intermittent: 9 units

Typical of courses, which are offered from time to time are finite difference equations, calculus of variations, and applied control theory. The prerequisites will depend on the content of the course. (Three 50 minute lectures)

Prerequisites: 21-260 and 21-241 and 21-259

21-476 Introduction to Dynamical Systems

Intermittent: 9 units

This course is an introduction to differentiable dynamical systems. The material includes basic properties of dynamical systems, including the existence and uniqueness theory, continuation, singular points, orbits, and their classification. The Poincaré-Bendixson theorem and typical applications, like Liénard equations and Lotka-Volterra are also covered. An introduction to chaos as time permits. (Three 50 minute lectures)

Prerequisites: (21-242 or 21-241) and 21-261

21-484 Graph Theory

Spring: 9 units

Graph theory uses basic concepts to approach a diversity of problems and nontrivial applications in operations research, computer science and other disciplines. It is one of the very few mathematical areas where one is always close to interesting unsolved problems. Topics include graphs and subgraphs, trees, connectivity, Euler tours and Hamilton cycles, matchings, graph colorings, planar graphs and Euler's Formula, directed graphs, network flows, counting arguments, and graph algorithms. (Three 50 minute lectures)

Prerequisites: (21-228 or 15-251) and (21-241 or 21-242)

21-590 Practicum in Mathematical Sciences

All Semesters: 3 units

Students in this course gain experience with the application of mathematical models to business and/or industrial problems during an internship. The internship is set up by the student in consultation with a faculty member. The students must also have a mentor at the firm providing the internship, who together with the faculty member develops a description of the goals of the internship. The internship must include the opportunity to learn about problems which have mathematical content. Tuition is charged for this course.

21-599 Undergraduate Reading and Research

Fall and Spring

Individual reading courses or projects in mathematics and its applications. Prerequisites and units to be negotiated with individual instructors.

21-602 Introduction to Set Theory I

Fall: 12 units

The axioms of ZFC, ordinal arithmetic, cardinal arithmetic including König's lemma, class length induction and recursion, the rank hierarchy, the Mostowski collapse theorem, the H-hierarchy, the Δ_1 absoluteness theorem, the absoluteness of wellfoundedness, the reflection theorem for hierarchies of sets, ordinal definability, the model HOD, relative consistency, Gödel's theorem that HOD is a model of ZFC, constructibility, Gödel's theorem that L is a model of ZFC + GCH, the Borel and Projective hierarchies and their effective versions, Suslin representations for Σ^1_1 , Π^1_1 and Σ^1_2 , sets of reals, Shoenfield's absoluteness theorem, the complexity of the set of constructible reals, the combinatorics of club and stationary sets (including the diagonal intersection, the normality of the club filter, Fodor's lemma and its applications), Solovay's splitting theorem, model theoretic techniques commonly applied in set theory (e.g., elementary substructures, chains of models and ultrapowers), club and stationary subsets of $[X]^\omega$ and their combinatorics, Jensen's diamond principles and his proofs that they hold in L, Gregory's theorem and generalizations, constructions of various kinds of uncountable trees (including Aronszajn, special, Suslin, Kurepa), Jensen's square principles and elementary applications, the basic theory of large cardinals (including inaccessible, Mahlo, weakly compact and measurable cardinals), Scott's theorem that there are no measurable cardinals in L, Kunen's theorem that the only elementary embedding from V to V is the identity. Optional topic: SCH and Silver's theorem. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-329 Min. grade B and 21-300 Min. grade B

21-603 Model Theory I

Intermittent: 12 units

Similarity types, structures; downward Löwenheim Skolem theorem; construction of models from constants, Henkin's omitting types theory, prime models; elementary chains of models, basic two cardinal theorems, saturated models, basic results on countable models including Ryll-Nardzewski's theorem; indiscernible sequences, Ehrenfeucht-Mostowski models; introduction to stability, rank functions, primary models, and a proof of Morley's categoricity theorem; basic facts about infinitary languages, computation of Hanf-Morley numbers. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-604 Introduction to Recursion Theory

Intermittent: 12 units

Models of computation, computable functions, solvable and unsolvable problems, reducibilities among problems, recursive and recursively enumerable sets, the recursion theorem, Post's problem and the Friedberg-Muchnik theorem, general degrees and r.e. degrees, the arithmetical hierarchy, the hyper-arithmetical hierarchy, the analytical hierarchy, higher type recursion. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-355 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-610 Algebra I

Intermittent: 12 units

The structure of finitely generated abelian groups, the Sylow theorems, nilpotent and solvable groups, simplicity of alternating and projective special linear groups, free groups, the Nielsen-Schreier theorem. Vector spaces over division rings, field extensions, the fundamental Galois correspondence, algebraic closure. The Jacobson radical and the structure of semisimple rings. Time permitting, one of the following topics will be included: Wedderburn's theorem on finite division rings, Frobenius' Theorem. Prerequisite: Familiarity with the content of an undergraduate course on groups and rings. (Three 50 minute lectures)

Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-620 Real Analysis

Fall: 6 units

A review of one-dimensional, undergraduate analysis, including a rigorous treatment of the following topics in the context of real numbers: sequences, compactness, continuity, differentiation, Riemann integration. (Mini-course. Normally taken with 21-621.) (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-621 Introduction to Lebesgue Integration

Fall: 6 units

Construction of Lebesgue measure and the Lebesgue integral on the real line. Fatou's Lemma, the monotone convergence theorem, the dominated convergence theorem. (Mini-course. Normally taken with 21-620.) (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-620 Min. grade B

21-623 Complex Analysis

Intermittent: 12 units

The complex plane, holomorphic functions, power series, complex integration, and Cauchy's Theorem. Calculus of residues. Additional topics may include conformal mappings and the application of complex transforms to differential equations. (Three 50 minute lectures)

Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-624 Descriptive Set Theory

Intermittent: 12 units

The central theme of the course is the study of "definable" subsets of Polish spaces (a class of topological spaces containing many spaces studied across mathematics). In some sense, restricting attention to definable sets makes life nicer; for instance, (properly interpreted) the continuum hypothesis becomes true! And weird Banach-Tarski stuff doesn't happen. However, it comes at a price: equivalence relations can have more classes than elements, and acyclic graphs can become hard to properly color. For the first portion of the course we will work through the basic theory of Borel and analytic subsets of Polish spaces, highlighting their interaction with measure and Baire category. We will then focus on the modern theory of equivalence relations, paying special attention to orbit equivalence relations of group actions and connectedness relations of graphs. Along the way we will establish several classical dichotomy theorems. (Three 50 minute lectures)

Prerequisites: (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-329 Min. grade B

21-630 Ordinary Differential Equations

Intermittent: 12 units

Basic concepts covered are existence and uniqueness of solutions, continuation of solutions, continuous dependence, and stability. For autonomous systems, topics included are: orbits, limit sets, Liapunov's direct method, and Poincaré-Bendixson theory. For linear systems, topics included are: fundamental solutions, variation of constants, stability, matrix exponential solutions, and saddle points. Time permitting, one or more of the following topics will be covered: differential inequalities, boundary-value problems and Sturm-Liouville theory, Floquet theory. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-632 Introduction to Differential Equations

Fall: 12 units

This course serves as a broad introduction to Ordinary and Partial Differential Equations for beginning graduate students and advanced undergraduate students in mathematics, engineering, and the applied sciences. Mathematical sophistication in real analysis at the level of 21-355/356 is assumed. Topics include: essentials of Ordinary Differential Equations, origins of Partial Differential Equations, the study of model problems including the Poisson and Laplace equations, the heat equation, the transport equation, and the wave equation. (Three 50 minute lectures)

Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-640 Introduction to Functional Analysis

Spring: 12 units

Linear spaces: Hilbert spaces, Banach spaces, topological vector spaces. Hilbert spaces: geometry, projections, Riesz Representation Theorem, bilinear and quadratic forms, orthonormal sets and Fourier series. Banach spaces: continuity of linear mappings, Hahn-Banach Theorem, uniform boundedness, open-mapping theorem. Closed operators, closed graph theorem. Dual spaces: weak and weak-star topologies (Banach-Alaoglu Theorem), reflexivity. Space of bounded continuous functions and its dual. Linear operators and adjoints: basic properties, null spaces and ranges. Compact operators. Sequences of bounded linear operators: weak, strong and uniform convergence. Introduction to spectral theory: Notions of spectrum and resolvent set of bounded operators, spectral theory of compact operators. Time permitting: Fredholm Alternative. Time permitting: Stone-Weierstrass Theorem. (Three 50 minute lectures)

Prerequisites: (21-236 Min. grade B or 21-651 Min. grade B) and (21-720 Min. grade B or 21-236 Min. grade B)

21-651 General Topology

Fall: 12 units

Metric spaces: continuity, compactness, Arzela-Ascoli Theorem, completeness and completion, Baire Category Theorem. General topological spaces: bases and subbases, products, quotients, subspaces, continuity, topologies generated by sets of functions, homeomorphisms. Convergence: nets, filters, and the inadequacy of sequences. Separation: Hausdorff spaces, regular spaces, completely regular spaces, normal spaces, Urysohn's Lemma, Tietze's Extension Theorem. Connectedness. Countability conditions: first and second countability, separability, Lindelöf property. Compactness: Tychonoff's Theorem, local compactness, one-point compactification. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-660 Introduction to Numerical Analysis I

Spring: 12 units

Finite precision arithmetic, interpolation, spline approximation, numerical integration, numerical solution of linear and nonlinear systems of equations, optimization in finite dimensional spaces. (Three 50 minute lectures)

Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-670 Linear Algebra for Data Science

Fall: 6 units

This course is designed to present and discuss those aspects of Linear Algebra that are most important in Data Analytics. The emphasis will be on developing intuition and understanding how to use linear algebra, rather than on proofs. (Three 50 minute lectures)

Prerequisites: 21-373 Min. grade B and 21-355 Min. grade B

21-671 Computational Linear Algebra

Fall: 12 units

This is a survey of methods in computational linear algebra. Topics covered in this course focus around algorithms for solving (dense or large and sparse) linear systems. Regularization and underdetermined systems will be discussed in detail. Rather than assuming prior knowledge in numerical analysis or matrix theory, we will introduce standard methods or results when needed. In this way, much of the material is self-contained. Theoretical and experimental results will be covered accordingly, with an emphasis on cost, stability, and convergence. (Three 50 minute lectures)

Prerequisites: (21-242 or 21-241 or 21-240) and (21-268 or 21-269 or 21-259)

21-681 Stochastic Calculus in Finance

All Semesters: 6 units

This is a graduate-level introduction to continuous-time equilibrium asset pricing models. Using tools from Ito calculus, the first part of the course covers the benchmark case of complete, frictionless markets, for which a fairly general theory and a number of solvable examples have been developed. The second part of the course then provides an overview of cutting-edge research on extensions of the baseline model that account for "flaws and frictions" such as heterogeneous beliefs, trading costs, or asymmetric information. In the third part of the course, students will present a related research paper, chosen together with the instructor in accordance with their background and research interests. (One 80 minute lecture)

Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-690 Methods of Optimization

Intermittent: 12 units

An introduction to the theory and algorithms of linear and nonlinear programming with an emphasis on modern computational considerations. The simplex method and its variants, duality theory and sensitivity analysis. Large-scale linear programming. Optimality conditions for unconstrained nonlinear optimization. Newton's method, line searches, trust regions and convergence rates. Constrained problems, feasible-point methods, penalty and barrier methods, interior-point methods. (Three 50 minute lectures)

Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-701 Discrete Mathematics

Fall: 12 units

Combinatorial analysis, graph theory with applications to problems in computational complexity, networks, and other areas. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

21-702 Set Theory II

Spring: 12 units

This course is a sequel to 21-602 Set Theory. The main goal is to prove Solovay's theorem that $\text{Con}(\text{ZFC} + \text{an inaccessible cardinal})$ implies $\text{Con}(\text{ZF} + \text{DC} + \text{every set of reals is Lebesgue measurable})$. Topics covered include absoluteness theorems, Borel codes, the Levy collapse, product forcing, relative constructibility, and the basics of iterated forcing up to the consistency of Martin's Axiom. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-455 Min. grade B or 21-235 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-602 Min. grade B

21-703 Model Theory II

All Semesters: 12 units

The course concentrates in what is considered "main stream model theory" with its Shelah's classification theory (known also as Stability). Among the topics to be presented are stability, superstability, the theory of various notions of primeness, rank functions, forking calculus, the stability spectrum theorem, finite equivalence relations theorem, stable groups (up to and including the Macintyre-Cherlin-Shelah theorem on super-stable fields), and some elementary geometric model theory. If time permits also: basic facts about infinitary languages, computation of Hanf-Morley numbers; some of the Ax-Kochen-Ershov theory of model theory for fields with valuations (will apply this to solve Artin's conjecture). (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-603 Min. grade B

Course Website: <http://www.math.cmu.edu/~rami/mt2.11.desc.html>

21-720 Measure and Integration

Fall: 12 units

The Lebesgue integral, absolute continuity, signed measures and the Radon-Nikodym Theorem, L_p spaces and the Riesz Representation Theorem, product measures and Fubini's Theorem. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-721 Probability

Spring: 12 units

Probability spaces, random variables, expectation, independence, Borel-Cantelli lemmas. Kernels and product spaces, existence of probability measures on infinite product spaces, Kolmogorov's zero-one law. Weak and strong laws of large numbers, ergodic theorems, stationary sequences. Conditional expectation: characterization, construction and properties. Relation to kernels, conditional distribution, density. Filtration, adapted and predictable processes, martingales, stopping times, upcrossing inequality and martingale convergence theorems, backward martingales, optional stopping, maximal inequalities. Various applications of martingales: branching processes, Polya's urn, generalized Borel-Cantelli, Levy's 0-1 law, martingale method, strong law of large numbers, etc. Weak convergence of probability measures, characteristic functions of random variables, weak convergence in terms of characteristic functions. Central limit theorem, Poisson convergence, Poisson process. Large deviations, rate functions, Cramer's Theorem. (Three 50 minute lectures)

Prerequisites: (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-720 Min. grade B

21-723 Advanced Real Analysis

Spring: 12 units

This course is a sequel to 21-720 Measure and Integration. It is meant to introduce students to a number of important advanced topics in analysis. Topics include: distributions, Fourier series and transform, Sobolev spaces, Bochner integration, basics of interpolation theory, integral transforms. (Three 50 minute lectures)

Prerequisites: (21-456 Min. grade B or 21-356 Min. grade B or 21-236 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-720 Min. grade B

21-724 Sobolev Spaces

Intermittent: 12 units

Weak derivatives, Sobolev spaces of integer order, embedding theorems, interpolation inequalities, traces. (Three 50 minute lectures)

Prerequisites: (21-236 Min. grade B or 21-356 Min. grade B or 21-456 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-720 Min. grade B

21-732 Partial Differential Equations I

Fall: 12 units

An introduction to the modern theory of partial differential equations. Including functional analytic techniques. Topics vary slightly from year to year, but generally include existence, uniqueness and regularity for linear elliptic boundary value problems and an introduction to the theory of evolution equations. (Three 50 minute lectures)

Prerequisites: 21-723 Min. grade B and 21-632 Min. grade B and 21-640 Min. grade B and (21-237 Min. grade B or 21-373 Min. grade B)

21-737 Probabilistic Combinatorics

Intermittent: 12 units

This course covers the probabilistic method for combinatorics in detail and introduces randomized algorithms and the theory of random graphs. Methods covered include the second moment method, the Rado and #246;dnibble, the Lovász and #225;sz local lemma, correlation inequalities, martingale's and tight concentration, Janson's inequality, branching processes, coupling and the differential equations method for discrete random processes. Objects studied include the configuration model for random regular graphs, Markov chains, the phase transition in the Erdős and #246;s-Rado and #233;nyi random graph, and the Barabási and #225;si-Albert preferential attachment model. (Three 50 minute lectures)

Prerequisites: 21-301 and (36-218 or 36-225 or 15-259 or 21-325)

21-738 Extremal Combinatorics

Intermittent: 12 units

Classical problems and results in extremal combinatorics including the Turán and #225;n and Zarankiewicz problems, the Erdős and #337;s-Stone theorem and the Erdős-Simonovits stability theorem. Extremal set theory including the Erdős and #337;s-Rado sunflower lemma and variations, VC-dimension, and Kneser's conjecture. The Szemerédi regularity lemma. Algebraic methods including finite field constructions and eigenvalues and expansion properties of graphs. Shannon capacity of graphs. Chromatic number of R_n and Borsuk's conjecture. Graph decomposition including Graham-Pollack and Baranyai's theorem. (Three 50 minute lectures)

Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-742 Calculus Of Variations

Intermittent: 12 units

Classical fixed endpoint examples. Fixed endpoint problems in classes of absolutely continuous functions: existence via lower semicontinuity. Tonelli's existence theorem. Euler-Lagrange and DuBois Reymond equations, transversality conditions, Weierstrass field theory, Hamilton-Jacobi theory. Problems with constraints. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-723 Min. grade B

21-752 Algebraic Topology

Fall and Spring: 12 units

Topology is a less rigid variant of geometry that studies shapes of spaces. Algebraic topology associates algebraic invariants, such as groups or rings, to such spaces. This is achieved by building a space from simpler ones or by algebraically keeping track of how to map a simple space into a given space. This course will cover the fundamental group and covering spaces, homology theories, and the cohomology ring of a space (time permitting). (Three 50 minute lectures)

Prerequisites: 21-651 Min. grade B and (21-355 Min. grade B or 21-235 Min. grade B or 21-455 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-759 Differential Geometry

Intermittent: 12 units

Manifolds in Euclidean spaces, curves and surfaces, principal curvatures, geodesics. Surfaces with constant mean curvature, minimal surfaces. Abstract differentiable manifolds, tangent spaces, vector bundles, affine connections, parallelisms, covariant gradients, Cartan torsion, Riemann curvature. Riemannian geometry, Lie groups. Familiarity with analysis in finite dimensional spaces will be assumed. (Three 50 minute lectures)

Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-762 Finite Element Methods

Intermittent: 12 units

Finite element methods for elliptic boundary value problems. Analysis of errors, approximation by finite element spaces. Efficient implementation of finite element spaces. Efficient implementation of finite element algorithms, finite element methods for parabolic and eigenvalue problems, effects of curved boundaries. Numerical quadrature, non-conforming methods. (Three 50 minute lectures)

Prerequisites: (21-456 Min. grade B or 21-236 Min. grade B or 21-356 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-765 Introduction to Parallel Computing and Scientific Computation

Spring: 9 units

Course objectives: to develop structural intuition of how the hardware and the software work, starting from simple systems to complex shared resource architectures; to provide guidelines about how to write and document a software package; to familiarize the audience with the main parallel programming techniques and the common software packages/libraries. (One 110 minute lecture)

Prerequisites: (21-455 Min. grade B or 21-235 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: <http://www.math.cmu.edu/~florin/M21-765/index.html>
(<http://www.math.cmu.edu/~florin/M21-765/>)

21-770 Introduction to Continuum Mechanics

Spring: 12 units

General discussion of the behavior of continuous bodies with an emphasis on those concepts common to the description of all continuous bodies. Specific examples from elasticity and fluid mechanics. Familiarity with analysis in finite dimensional spaces will be assumed. (Three 50 minute lectures)

Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-800 Advanced Topics in Logic

Intermittent: 12 units

This course affords students with the opportunity to study topics which are in the area of expertise of the instructor. This course may be taken more than once if content is sufficiently different. Course prerequisites will depend on the content of the course. Please see the course URL for semester-specific topics. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: <https://www.cmu.edu/math/courses/special-topics.html>

21-801 Advanced Topics in Discrete Mathematics

Intermittent: 12 units

Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B)

21-803 Model Theory III

All Semesters: 12 units

We will concentrate in classification theory for first-order theories. The theory was developed mostly by Saharon Shelah presented in his 1978 (2nd ed 1990) book and in several hundreds of papers. We will present a modern overview of Shelah's theory incorporating few recent innovations and simplifications. The development of the theory was motivated by set-theoretic questions like: "what is the asymptotic behavior of the function $I(\aleph_\alpha, T)$ as a function of α ?" and "what is the first λ such that an uncountable first-order stable theory T is stable in λ ?" Surprisingly the full answer to such combinatorial set-theoretic questions led for a development and discovery of a conceptually rich theory which seems to be related to aspects of commutative algebra and algebraic-geometry. This theory found several applications in the form of solving fundamental problems in classical fields of mathematics among them geometry and number theory. The focus will be on the simplest and most fundamental aspects of the pure theory. Primarily around a notion called forking and various characterizations of classes of theories. (Three 50 minute lectures)

Prerequisites: (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-703 Min. grade B

21-820 Advanced Topics in Analysis

Intermittent: 12 units

Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different.

Prerequisites: (21-456 Min. grade B or 21-356 Min. grade B or 21-236 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B)

Course Website: <https://www.cmu.edu/math/courses/special-topics.html>

21-830 Advanced Topics in Partial Differential Equations

All Semesters: 12 units

Course topics will vary depending on the semester and instructor. May be taken more than once if content is sufficiently different.

Prerequisites: (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-632 Min. grade B

21-832 Partial Differential Equations II

Intermittent: 12 units

Elliptic boundary value problems, Green's theorem calculations, integral equation methods, variational formulations and Galerkin's method, regularity theory, parabolic problems and semigroups. (Three 50 minute lectures)

Prerequisites: (21-356 Min. grade B or 21-236 Min. grade B or 21-456 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-732 Min. grade B

21-849 Special Topics

Intermittent: 12 units

This course affords students with the opportunity to study topics which are in the area of expertise of the instructor. This course may be taken more than once if content is sufficiently different. Course prerequisites will depend on the content of the course. Please see the course URL for semester-specific topics. (Three 50 minute lectures)

Prerequisites: 21-355 Min. grade B and 21-373 Min. grade B

Course Website: <https://www.cmu.edu/math/courses/special-topics.html>

21-860 Advanced Topics in Numerical Analysis

Intermittent: 12 units

Content varies. May be taken more than once if content is sufficiently different. (Three 50 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-660 Min. grade B

21-880 Stochastic Calculus

All Semesters: 12 units

This is a first Ph.D.-level course in stochastic calculus for continuous-time processes. It includes martingales and semi-martingales, Brownian motion, the Poisson process, representation of continuous martingales as time-changed Brownian motions, construction of the Ito integral, and Ito's formula. (Two 80 minute lectures)

Prerequisites: (21-455 Min. grade B or 21-355 Min. grade B or 21-235 Min. grade B) and (21-237 Min. grade B or 21-373 Min. grade B) and 21-721 Min. grade B

21-882 Advanced Topics in Financial Mathematics

Intermittent: 12 units

Content varies. May be taken more than once if content is sufficiently different. (Two 80 minute lectures)

Prerequisites: (21-235 Min. grade B or 21-455 Min. grade B or 21-355 Min. grade B) and (21-373 Min. grade B or 21-237 Min. grade B) and 21-721 Min. grade B

21-901 Master's Degree Research

All Semesters

This course is for students admitted to the Mathematical Sciences Honors Degree Program. It allows for students to engage in research activities related to their Master's thesis, under the supervision of their thesis supervisor. The supervisor should be contacted prior to enrollment in 21-901, as they are required to provide consent for the student's enrollment to the Academic Program Coordinator, who authorizes enrollment in this course.

Department of Physics

Scott Dodelson, Department Head
Location: Wean Hall 7325

Gillian Lynn Ryan, Director of Undergraduate Affairs
Location: Wean Hall 7303

Amanda Black, Academic Program Manager
Location: Wean Hall 7319
www.cmu.edu/physics/ (<http://www.cmu.edu/physics/>)

Physics, one of the basic sciences, has its origin in the irrepressible human curiosity to explore and understand the natural world. This fundamental urge to discover has led to the detailed understanding of a remarkable variety of physical phenomena. Our knowledge now encompasses the large-scale movement of galaxies, the minute motions within atoms and nuclei, and the complex structure of the assemblies of molecules that make life possible. The spectacular expansion of our comprehension of the physical world forms an impressive part of the intellectual and cultural heritage of our times. The opportunity to add to this heritage is an important source of motivation for young physicists. The application of discoveries in physics to the solution of complex modern technological problems offers a vast field in which physicists make decisive contributions. The interplay of pure and applied physics has always been fruitful and today ensures many rewarding career opportunities for physics students. The deep understanding of the physical world developed by physics majors prepares them for success in a wide variety of careers well beyond physics, from medicine to all the sciences and engineering.

Carnegie Mellon's undergraduate curriculum in physics has been carefully designed to provide a firm knowledge of the basic principles of physics, an appreciation of a wide range of physical problems of current interest, and the capacity to formulate and solve new problems. In addition to classwork and problem solving, the curriculum includes studying physical phenomena in the laboratory. Physics students are strongly encouraged to go beyond the formal theoretical and experimental course work and become involved in research projects under the guidance of individual faculty members.

Students may choose from a variety of degree options. The objectives and requirements for each of these options are described below. Each allows considerable latitude in the choice of electives:

- B.S. in Physics (p. 659)
- B.A. in Physics (p. 661)
- B.S. in Physics with Tracks in: (p. 662)
 - Applied Physics
 - Astrophysics
 - Biological Physics
 - Chemical Physics
 - Computational Physics
- Minor in Physics (p. 665)

Students pursuing a B.S. in Physics, with any track, will take all courses from the Physics, Mathematics, and Technical Core lists, and take an appropriate selection of courses from the Technical, Non-Technical, Physics Breadth, and Qualifying Physics Elective lists. These lists are detailed below.

- Physics Core (p. 659)
- Mathematics Core (p. 659)
- Technical Core (p. 659)
- Technical Electives (p. 662)
- Non-Technical Electives (p. 583)
- Physics Breadth Electives (p. 662)
- Qualifying Physics Electives (p. 662)
- Recommended Electives for Physics Graduate School (p. 662)
- Physics Graduate Courses (p. 662)

Through the judicious choice of elective courses, a double major program combining physics and another discipline can be readily achieved. A minor in physics is also offered for those students who major in other disciplines. The student, with the help of their faculty advisors, can easily build a program that aims at specific career objectives.

- Physics as an Additional Major (p. 664)
- Physics as a Dual Degree (p. 664)
- Minor in Physics (p. 665)

The Department maintains an active and wide-ranging program of advising. Beyond aiding in academic planning, the Director of Undergraduate Affairs

can also assist students in finding research work during the academic year, technical jobs and internships for the summer, as well as planning and executing the necessary steps for gaining employment or continuing their studies beyond the bachelor's degree. Whether students follow a standard curriculum or not, they should consult their academic advisor at least once every semester.

- Sample Schedule for a B.S. in Physics (p. 659)

B.S. in Physics

B.S. degree candidates can choose studies in not only a wide variety of intermediate and advanced topics in physics but also a range of material in other science or engineering fields. The B.S. degree provides a solid foundation for students wishing to go on to graduate work in physics or any of a large number of fields in pure or applied science or engineering for which a sound grasp of physics and mathematics is essential. This program also provides excellent preparation for careers in teaching, for work in industrial or governmental research and development, or for other employment in business or industry with a significant scientific component.

Degree Requirements

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

| | | Units |
|----------------------------------|---|------------|
| 33-121 | Physics I for Science Students | 12 |
| or 33-151 | Matter and Interactions I | |
| Corequisite for 33-121 is 21-120 | | |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| or 33-152 | Matter and Interactions II | |
| 33-104 | Experimental Physics | 9 |
| 33-201 | Physics Sophomore Colloquium I | 2 |
| 33-211 | Physics III: Modern Essentials | 10 |
| 33-231 | Physical Analysis | 10 |
| 33-202 | Physics Sophomore Colloquium II | 2 |
| 33-228 | Electronics I | 10 |
| 33-232 | Mathematical Methods of Physics | 10 |
| 33-234 | Quantum Physics | 10 |
| 33-301 | Physics Upperclass Colloquium I | 1 |
| 33-331 | Physical Mechanics I | 10 |
| 33-338 | Intermediate Electricity and Magnetism I | 10 |
| 33-341 | Thermal Physics I | 10 |
| 33-302 | Physics Upperclass Colloquium II | 1 |
| 33-340 | Modern Physics Laboratory | 10 |
| Total Physics Core Units | | 129 |

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

| | | Units |
|-------------------------------------|------------------------------------|-----------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-259 | Calculus in Three Dimensions | 10 |
| Total Mathematics Core Units | | 30 |

Technical Core:

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. The following three courses have been selected specifically for physics majors to give them the technical breadth they need.

| | Units |
|--|-------|
| 03-121 Modern Biology ¹ | 9 |
| 09-105 Introduction to Modern Chemistry I ² | 10 |
| 15-110 Principles of Computing ³ | 10-12 |
| or 15-112 Fundamentals of Programming and Computer Science | |

Total Technical Core Units 29-31

[1] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[2] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[3] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

Physics majors can choose to increase the breadth or depth of their studies through their choices of Technical Electives. Students may choose these electives individually or may take a pre-set selection of technical electives known as a "track" to focus on a specific subfield of physics. **The five available tracks are detailed here.**

| | Units |
|---|-------|
| 33-xxx Physics Breadth Elective | 9-12 |
| 33-xxx Three Qualifying Physics Electives | 27-36 |
| 21-2xx Mathematics Elective | 9-10 |
| xx-xxx Three STEM Electives ⁴ | 27-36 |

Total Technical Electives Units 72-94

[4] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Non-Technical Electives:

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large.

| | Units |
|--|-------|
| 99-101 Computing @ Carnegie Mellon | 3 |
| 76-101 Interpretation and Argument | 9 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 38-110 ENGAGE in Service | 1 |
| 38-220 ENGAGE in the Arts | 2 |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| 38-330 ENGAGE in Wellness: Looking Outward | 1 |
| 38-430 ENGAGE in Wellness: Looking Forward | 1 |
| 38-304 Reading and Writing Science ⁵ | 6 |
| xx-xxx Cultural/Global Understanding Elective ⁶ | 9 |
| xx-xxx Four Non-Technical Electives ⁷ | 36 |

Total Non-Technical Units 75

[5] Refer to the Mellon College of Science's Science and Society list for alternate courses that will fulfill this requirement. Placement credit may not be used.

[6] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[7] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required.

| | Units |
|------------------------------------|-------|
| xx-xxx Free Electives ⁸ | 1-26 |

Total Free Elective Units 1-26

[8] A maximum of 9 units of physical education and/or military science and/or STUCO courses may be taken as free electives.

First Year

| | Units |
|---|-------|
| Fall | |
| 99-101 Computing @ Carnegie Mellon | 3 |
| 38-101 EUREKA!: Discovery and Its Impact | 6 |
| 33-121 Physics I for Science Students | 12 |
| or 33-151 Matter and Interactions I | |
| Corequisite for 33-121 is 21-120 & for 33-151 is 21-122 | |
| 21-120 Differential and Integral Calculus | 10 |
| or 21-122 Integration and Approximation | |
| xx-xxx MCS/Physics Technical Core Requirement 1 of 3 | 9-12 |
| 76-101 Interpretation and Argument | 9 |
| or 76-100 Reading and Writing in an Academic Context | |

First-Year Fall Units 49-52

| | Units |
|---|-------|
| Spring | |
| 33-142 Physics II for Engineering and Physics Students | 12 |
| or 33-152 Matter and Interactions II | |
| Corequisite for 33-142 is 21-122 & for 33-152 is 21-259 | |
| 33-104 Experimental Physics | 9 |
| 21-122 Integration and Approximation | 10 |
| or 21-259 Calculus in Three Dimensions | |
| xx-xxx MCS/Physics Technical Core Requirement 2 of 3 | 9-12 |
| xx-xxx Non-Technical Elective 1 of 4 | 9 |

First-Year Spring Units 49-52

Sophomore Year

| | Units |
|--|-------|
| Fall | |
| 33-201 Physics Sophomore Colloquium I | 2 |
| 33-211 Physics III: Modern Essentials | 10 |
| 33-231 Physical Analysis | 10 |
| 21-259 Calculus in Three Dimensions (if not already taken) | 10 |
| xx-xxx MCS/Physics Technical Core Requirement 3 of 3 | 9-12 |
| xx-xxx Cultural/Global Understanding Elective | 9-12 |

Sophomore Fall Units 50-56

| | Units |
|---|-------|
| Spring | |
| 38-230 ENGAGE in Wellness: Looking Inward | 1 |
| 33-202 Physics Sophomore Colloquium II | 2 |
| 33-228 Electronics I | 10 |
| 33-232 Mathematical Methods of Physics | 10 |
| 33-234 Quantum Physics | 10 |
| xx-xxx Technical Elective 1 of 8 | 9-12 |

Sophomore Spring Units 42-45

Junior Year

| | Units |
|---|-------|
| Fall | |
| 38-330 ENGAGE in Wellness: Looking Outward | 1 |
| 33-301 Physics Upperclass Colloquium I | 1 |
| 33-331 Physical Mechanics I | 10 |
| 33-338 Intermediate Electricity and Magnetism I | 10 |
| 33-341 Thermal Physics I | 10 |
| xx-xxx Technical Elective 2 of 8 | 9-12 |

Junior Fall Units 41-44

| | Units |
|--|-------|
| Spring | |
| 33-302 Physics Upperclass Colloquium II | 1 |
| 38-304 Reading and Writing Science (Science and Society) | 6 |
| 33-340 Modern Physics Laboratory | 10 |
| 38-110 ENGAGE in Service | 1 |
| xx-xxx Technical Elective 3 of 8 | 9-12 |
| xx-xxx Technical Elective 4 of 8 | 9-12 |
| xx-xxx Non-Technical Elective 2 of 4 | 9-12 |

Junior Spring Units 45-54

Sample Schedule (No Track)

BEGINNING FALL 2015 AND BEYOND

Senior Year

| Fall | | Units |
|--------|-------------------------------------|-------|
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| xx-xxx | Technical Elective 5 of 8 | 9-12 |
| xx-xxx | Technical Elective 6 of 8 | 9-12 |
| xx-xxx | Non-Technical Elective 3 of 4 | 9-12 |
| xx-xxx | Free Elective | 9-12 |
| xx-xxx | Free Elective | 9-12 |

Senior Fall Units 48-63

| Spring | | Units |
|--------|-------------------------------|-------|
| xx-xxx | Technical Elective 7 of 8 | 9-12 |
| xx-xxx | Technical Elective 8 of 8 | 9-12 |
| xx-xxx | Non-Technical Elective 4 of 4 | 9-12 |
| xx-xxx | Free Elective | 9-12 |

Senior Spring Units 36-48**B.A. in Physics**

The Bachelor of Arts degree in Physics offers a flexible program that allows students to combine the study of Physics with the opportunity to do intensive work in substantive areas such as liberal arts, teaching, business or law. With up to 80 units of free electives, it is feasible for students to obtain, for example, an additional major with a department in the Dietrich College of Humanities and Social Sciences, the College of Fine Arts, or the Tepper School of Business. It is expected that students will focus their elective courses in a well-defined academic area. Students must meet with the Director of Undergraduate Affairs and construct an approved plan of study.

The requirements for the B.A. degree are the same as for the B.S. degree, except that 6 of the Physics, Mathematics and Technical Electives in the B.S. program become Free Electives in the BA program. These requirements are listed below.

Degree Requirements**Physics Core:**

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

| | | Units |
|----------------------------------|---|-------|
| 33-121 | Physics I for Science Students | 12 |
| or 33-151 | Matter and Interactions I | |
| Corequisite for 33-121 is 21-120 | | |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| or 33-152 | Matter and Interactions II | |
| Corequisite for 33-142 is 21-122 | | |
| 33-104 | Experimental Physics | 9 |
| 33-201 | Physics Sophomore Colloquium I | 2 |
| 33-211 | Physics III: Modern Essentials | 10 |
| 33-231 | Physical Analysis | 10 |
| 33-202 | Physics Sophomore Colloquium II | 2 |
| 33-228 | Electronics I | 10 |
| 33-232 | Mathematical Methods of Physics | 10 |
| 33-234 | Quantum Physics | 10 |
| 33-301 | Physics Upperclass Colloquium I | 1 |
| 33-331 | Physics Mechanics I | 10 |
| 33-338 | Intermediate Electricity and Magnetism I | 10 |
| 33-341 | Thermal Physics I | 10 |
| 33-302 | Physics Upperclass Colloquium II | 1 |
| 33-340 | Modern Physics Laboratory | 10 |

Total Physics Core Units 129**Mathematics Core:**

All Physics Majors take these courses from the Department of Mathematics to support their studies in Physics.

| | | Units |
|--------|------------------------------------|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-259 | Calculus in Three Dimensions | 10 |

Total Mathematics Core Units 30**Technical Core:**

All students in the Mellon College of Science take courses in the Life Sciences, Physical Sciences, and Mathematics, Statistics, or Computer Science to gain the technical breadth necessary for interdisciplinary work. These three courses have been selected specifically for Physics Majors to give them the technical breadth they need

| | | Units |
|-----------|--|-------|
| 03-121 | Modern Biology ⁹ | 9 |
| 09-105 | Introduction to Modern Chemistry ¹⁰ | 10 |
| 15-112 | Fundamentals of Programming and Computer Science ¹¹ | 10-12 |
| or 15-110 | Principles of Computing | |

Total Technical Core Units 29-31

[9] If 03-121 is satisfied through placement credit, students should refer to the Mellon College of Science's Life Sciences list to fulfill technical breadth requirement A.

[10] If 09-105 is satisfied through placement credit, students should refer to the Mellon College of Science's Physical Sciences list to fulfill technical breadth requirement B.

[11] If 15-112 is satisfied through placement credit, students should refer to the Mellon College of Science's STEM Course list to fulfill technical breadth requirement D.

Technical Electives:

While students pursuing a B.S. in Physics are required to take a minimum of 8 Physics, Mathematics, and STEM electives, students pursuing a B.A. in Physics need only take a minimum of 2 Qualifying Physics Electives.

| | | Units |
|--------|----------------------------------|-------|
| 33-xxx | Two Qualifying Physics Electives | 18-24 |

Total Technical Electives 18-24**Non-Technical Electives:**

The Mellon College of Science requires that all students take a variety of non-technical courses to strengthen their understanding of both themselves and the world at large. The precise requirements are different for those entering before and after the Fall of 2015.

| | | Units |
|--------|--|-------|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| 38-101 | EUREKA!: Discovery and Its Impact | 6 |
| 38-110 | ENGAGE in Service | 1 |
| 38-220 | ENGAGE in the Arts | 2 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| 38-304 | Reading and Writing Science ¹² | 6 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |
| xx-xxx | Cultural/Global Understanding Elective ¹³ | 9 |
| xx-xxx | Four Non-Technical Electives ¹⁴ | 36 |

Total Non-Technical Elective Units 75

[12] Refer to the Mellon College of Science's Science and Society list for alternate courses that will fulfill this requirement. Placement credit may not be used.

[13] Refer to the Mellon College of Science's Cultural/Global Understanding list for courses that will fulfill this requirement. Placement credit may not be used.

[14] Refer to the Mellon College of Science's Arts, Humanities, and Social Sciences section for courses that will fulfill the non-technical electives requirement. Up to 18 units may be fulfilled through placement credit.

Free Electives:

All students must complete a minimum of 360 units to earn a bachelor's degree in the Mellon College of Science. Students are welcome to take more than the minimum 360 units required. The B.A. in Physics replaces 6 Technical Electives with Free Electives, compared to the B.S. in Physics.

| | | |
|-----------------------------|------------------------------|----------------|
| xx-xxx | Free Electives ¹⁵ | Units 72-80 |
| Total Free Electives | | 72-80 |

[15] A maximum of 9 units of physical education and/or military science and/or StuCo courses may be taken as free electives.

Physics Electives

Physics Breadth Electives

Students pursuing a B.S. in Physics must take at least one course from the Physics Breadth Elective list to gain experience in a subfield of physics. Some tracks have this course prescribed, while others allow free choice from this list. All of these courses may also be taken as Qualifying Physics Electives, but they may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

| | | |
|--------|--|-------|
| | | Units |
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-226 | Physics of Energy | 9 |
| 33-353 | Intermediate Optics (Alt. Fall - F22, F24) | 12 |
| 33-355 | Nanoscience and Nanotechnology (Alt. Fall - F23, F25) | 9 |
| 33-441 | Introduction to Biophysics | 10 |
| 33-444 | Introduction to Nuclear and Particle Physics | 9 |
| 33-448 | Introduction to Solid State Physics | 9 |
| 33-466 | Extragalactic Astrophysics and Cosmology | 9 |
| 33-467 | Astrophysics of Stars and the Galaxy | 9 |
| 33-650 | General Relativity | 9 |

Total Physics Breadth Elective Units 9-12

Qualifying Physics Electives

Students pursuing a B.S. in Physics must take at least three courses totaling at least 27 units from the Qualifying Physics Elective list, not including the 100-level courses. Some tracks have these courses prescribed, while others allow free choice from this list, allowing students to choose between broad and in-depth study. Students pursuing a B.A. in Physics must take at least two courses totaling at least 18 units from this list. Students pursuing a Minor in Physics must take at least three courses totaling at least 27 units from this list or non-prescribed courses from the Physics Core list. While all courses on the Physics Breadth Elective list are also on the Qualifying Physics Elective list, a course may not fulfill both requirements simultaneously. Certain courses are offered only in alternate years, as indicated.

| | | |
|--------|--|------|
| 33-114 | Physics of Musical Sound (B.A. and Minor only) ¹⁶ | 9 |
| 33-115 | Physics for Future Presidents (B.A. and Minor only) ¹⁶ | 9 |
| 33-120 | Science and Science Fiction (B.A. and Minor only) ¹⁶ | 9 |
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-226 | Physics of Energy | 9 |
| 33-241 | Introduction to Computational Physics | 9 |
| 33-332 | Physical Mechanics II | 10 |
| 33-339 | Intermediate Electricity and Magnetism II | 10 |
| 33-342 | Thermal Physics II | 10 |
| 33-350 | Undergraduate Research ¹⁷ | Var. |
| 33-353 | Intermediate Optics (Alt. Fall - F22, F24) | 12 |
| 33-355 | Nanoscience and Nanotechnology (Alt. Fall - F23, F25) | 9 |
| 33-441 | Introduction to Biophysics | 10 |
| 33-444 | Introduction to Nuclear and Particle Physics | 9 |
| 33-445 | Advanced Quantum Physics I | 9 |
| 33-446 | Advanced Quantum Physics II | 9 |
| 33-448 | Introduction to Solid State Physics | 9 |
| 33-451 | Senior Research ¹⁷ | Var. |
| 33-456 | Advanced Computational Physics | 9 |
| 33-466 | Extragalactic Astrophysics and Cosmology | 9 |
| 33-467 | Astrophysics of Stars and the Galaxy | 9 |
| 33-499 | Supervised Reading ¹⁷ | Var. |

| | | |
|--------|--|----|
| 33-650 | General Relativity | 9 |
| 33-658 | Quantum Computation and Quantum Information Theory | 10 |
| 33-659 | Quantum Hall Effect and Topological Insulators | 12 |
| 33-7xx | Physics Graduate Level Courses (see list below) | |

Total Qualifying Physics Electives Units 27-37

[16] Only one of these three courses (33-114, 33-115, and 33-120) may be used for the B.A. These classes may not be used as Qualifying Physics Electives for the B.S.

[17] Only one of these three courses (33-350, 33-451, and 33-499) of 9 units may be used as a Qualifying Physics Elective. Any exceptions must be approved by the Director of Undergraduate Affairs.

Qualifying Physics Electives Recommended for Physics Graduate School

Students planning to undertake graduate studies in physics are strongly advised to take the following courses, which count as Qualifying Physics Electives and STEM Electives.

| | | |
|--------|---|-------|
| | | Units |
| 33-332 | Physical Mechanics II | 10 |
| 33-339 | Intermediate Electricity and Magnetism II | 10 |
| 33-445 | Advanced Quantum Physics I | 9 |
| 33-446 | Advanced Quantum Physics II | 9 |

Qualifying Physics Electives Recommended for Graduate School in Physics

Physics Graduate Courses

These courses are intended for graduate students in physics, but may be taken by advanced undergraduates as Qualifying Physics or STEM Electives. **Undergraduate students require special permission of the instructor and the Director of Undergraduate Affairs to register for these classes.**

| | | |
|--------|---|-------|
| | | Units |
| 33-755 | Quantum Mechanics I | 12 |
| 33-756 | Quantum Mechanics II | 12 |
| 33-758 | Quantum Computation and Quantum Information Theory | 12 |
| 33-759 | Introduction to Mathematical Physics I | 12 |
| 33-761 | Classical Electrodynamics I | 12 |
| 33-762 | Classical Electrodynamics II | 12 |
| 33-765 | Statistical Mechanics | 12 |
| 33-767 | Biophysics: From Basic Concepts to Current Research | 12 |
| 33-769 | Quantum Mechanics III: Many Body and Relativistic Systems | 12 |
| 33-770 | Field Theory I | 12 |
| 33-771 | Field Theory II | 12 |
| 33-777 | Introductory Astrophysics | 12 |
| 33-778 | Introduction to Cosmology | 12 |
| 33-779 | Introduction to Nuclear and Particle Physics | 12 |
| 33-780 | Nuclear and Particle Physics II | 12 |
| 33-783 | Solid State Physics | 12 |

Physics Graduate Course Units Optional

Tracks for B.S. in Physics

Students seeking a B.S. in Physics may choose from 5 different Physics tracks, or opt to pursue no track. Each of these tracks fulfills the Technical Electives of the B.S. in Physics. The available tracks are:

- No Track (p. 663)
- Applied Physics (p. 663)
- Astrophysics (p. 663)
- Biological Physics (p. 663)
- Chemical Physics (p. 664)
- Computational Physics (p. 664)

The track descriptions and requirements are listed below.

No Track

Physics students wanting maximum freedom can opt not to select a track. The required Technical Electives are those described in the B.S. in Physics section above, and are reprinted below.

| | | Units |
|---------------------------------------|------------------------------------|--------------|
| 33-xxx | Physics Breadth Elective | 9-12 |
| 33-xxx | Three Qualifying Physics Electives | 27-37 |
| 21-2xx | Mathematics Elective | 9-10 |
| xx-xxx | Three STEM Electives ¹⁸ | 27-36 |
| Total Technical Elective Units | | 72-95 |

[18] STEM electives are any courses in MCS (including Physics), SCS, Statistics, CIT, and others explicitly approved by the Director of Undergraduate Affairs.

Applied Physics Track

The B.S. in Physics/Applied Physics Track is designed primarily for students who want to prepare for a career path that takes advantage of the diverse and expanding opportunities for employment in industrial and government laboratories with a B.S. degree. The program provides a solid foundation in the concepts of physics, as well as giving the student the experience and understanding of the application of these concepts. The track is intended to enhance computing and laboratory skills, and to introduce the application of physics to those subjects of particular interest to the student. Since the possible subject areas for study are so varied, the track will be tailored to each student's needs within the framework described below.

| | | Units |
|---|---|--------------|
| 33-448 | Introduction to Solid State Physics | 9 |
| xx-xxx | Computational Science Course ¹⁹ | 9-12 |
| xx-xxx | Four Applied Physics/Laboratory Electives ¹⁹ | 36-48 |
| 33-350 | Undergraduate Research ¹⁹ | 9 |
| or 33-451 | Senior Research | |
| 21-2xx | Mathematics Elective | 9-10 |
| Total Applied Track Elective Units | | 72-88 |

[19] The elective courses and research topic are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Research must be completed in a single 9-unit block.

Astrophysics Track

The B.S. in Physics/Astrophysics Track provides an option for those Physics majors who either want to specialize in this subfield or plan careers in astronomy or astrophysics. Career paths may include postgraduate training in astronomy or astrophysics or proceeding directly to jobs in these fields. The program provides a thorough foundation in the core physics program with electives concentrating in astrophysics.

| | | Units |
|--|--|--------------|
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-466 | Extragalactic Astrophysics and Cosmology | 9 |
| 33-467 | Astrophysics of Stars and the Galaxy | 9 |
| 33-350 | Undergraduate Research ²⁰ | 9 |
| or 33-451 | Senior Research | |
| 21-2xx | Mathematics Elective | 9-10 |
| xx-xxx | Three STEM Electives | 27-36 |
| Total Astrophysics Track Elective Units | | 72-82 |

[20] The research topic must be approved by the Director of Undergraduate Affairs and must be completed in a single 9-unit block.

Biological Physics Track

The B.S. in Physics/Biological Physics Track combines a rigorous foundation in undergraduate physics with courses in Biological Physics and Chemistry. It is particularly suitable for students preparing for post-baccalaureate careers in the expanding areas of biological and medical physics or for graduate study in biophysics. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

The Biological Physics Track is excellent preparation for Medical School.

All courses suggested for medical school applicants can be completed within this track. Students interested in both the Biological Physics Track

and the pre-medical program should consult with both the Director of Undergraduate Affairs in the Physics Department and the Director of the Health Professions Program for help in planning their programs.

Program optimized for Biological Physical studies:

| | | Units |
|--|---|--------------|
| 33-441 | Introduction to Biophysics | 10 |
| or 03-439 | Introduction to Biophysics | |
| 33-xxx | One Qualifying Physics Elective | 9-12 |
| 21-2xx | Mathematics Elective | 9-10 |
| 03-231 | Honors Biochemistry | 9 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 03-xxx | Two Biological Sciences Electives ²¹ | 18 |
| Total Biological Physics Track Elective Units | | 73-77 |

[21] The elective courses in Biological Sciences are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Program optimized for Medical School preparation:

| | | Units |
|---|--|------------|
| 03-121 | Modern Biology | 9 |
| or 03-151 | Honors Modern Biology | |
| 42-202 | Physiology | 9 |
| 03-124 | Modern Biology Laboratory | 9 |
| or 03-206 | Biomedical Engineering Laboratory | |
| or 03-343 | Experimental Techniques in Molecular Biology | |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 09-106 | Modern Chemistry II | 10 |
| or 09-221 | Laboratory I: Introduction to Chemical Analysis | |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| or 09-221 | Laboratory I: Introduction to Chemical Analysis | |
| 09-217 | Organic Chemistry I | 9 |
| or 09-219 | Modern Organic Chemistry | |
| 09-218 | Organic Chemistry II | 9 |
| or 09-220 | Modern Organic Chemistry II | |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |
| or 09-222 | Laboratory II: Organic Synthesis and Analysis | |
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| Corequisite for 33-121 is 21-120 | | |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| or 33-142 | Physics II for Engineering and Physics Students | |
| Corequisite for 33-122 is 21-122 | | |
| 33-100 | Basic Experimental Physics | 6 |
| 03-231 | Honors Biochemistry | 9 |
| or 03-232 | Biochemistry I | |
| 21-111 | Calculus I | 10 |
| or 21-120 | Differential and Integral Calculus | |
| 21-112 | Calculus II | 10 |
| (A semester of statistics may substitute for a semester of calculus at many medical schools.) ¹⁴ | | |
| or 21-122 | Integration and Approximation | |
| or 21-124 | Calculus II for Biologists and Chemists | |
| 36-200 | Reasoning with Data | 9 |
| or 36-202 | Methods for Statistics & Data Science | |
| or 36-247 | Statistics for Lab Sciences | |
| 76-101 | Interpretation and Argument | 9 |
| 76-xxx | English II Elective | 9 |
| 85-xxx | Psychology Elective (Intro to Psychology, Social Psychology) | 9 |
| xx-xxx | Intro to Sociology (not offered at CMU) | 9 |
| Total Biological Physics Track Elective Units | | 184 |

Chemical Physics Track

The B.S. in Physics/Chemical Physics Track is designed for students wishing to have a strong grounding in physics along with a specialization in physical chemistry and/or chemical physics. It is particularly suitable for those students planning on graduate studies in physics with an emphasis on chemical physics or chemistry. The program is sufficiently flexible that it can be readily adapted to the requirements of individual students. The student will first meet with the Director of Undergraduate Affairs to discuss interests and career goals and then choose electives that fulfill the requirements of the track.

| | Units |
|---|--------------|
| 33-xxx One Physics Breadth Elective | 9-12 |
| 21-2xx Mathematics Elective | 9-10 |
| 09-106 Modern Chemistry II | 10 |
| 09-344 Physical Chemistry (Quantum): Microscopic Principles of Physical Chemistry | 9 |
| 09-345 Physical Chemistry (Thermo): Macroscopic Principles of Physical Chemistry | 9 |
| 09-xxx Three Chemistry Electives ²² | 27 |
| Total Chemical Physics Track Elective Units | 73-77 |

[22] The elective courses in Chemistry are decided after consultation with, and approval by, the Director of Undergraduate Affairs.

Computational Physics Track

The B.S. in Physics/Computational Physics Track is intended to fill the increasing demand for physics graduates who are skilled in computational and numerical techniques that are used in the analysis of physical problems in areas ranging from academia to Silicon Valley. The degree provides the student with a rigorous grounding in physics as well as in the foundations and practice of computational skills to address theoretical and applied problems in society. Flexibility in the degree requirements allows students to choose technical electives that prepare them for future careers in a range of emerging computational science fields including data science, artificial intelligence, and software development. Students who complete this track will also gain experience in the application of high-performance computing resources to a wide variety of problems.

| | Units |
|---|--------------|
| 33-241 Introduction to Computational Physics | 9 |
| 33-456 Advanced Computational Physics | 9 |
| 33-xxx One Physics Breadth Elective | 9-12 |
| 33-xxx One Qualifying Physics Elective or xx-xxx Computational Science Elective ²³ | 9-12 |
| 21-127 Concepts of Mathematics | 12 |
| 21-369 Numerical Methods | 9-12 |
| or 21-325 Probability | |
| or 36-225 Introduction to Probability Theory | |
| 15-122 Principles of Imperative Computation | 12 |
| 15-150 Principles of Functional Programming | 12 |
| Total Computational Physics Track Elective Units | 81-90 |

[23] Selected in consultation with, and requires approval of, the Director of Undergraduate Affairs. Common choices outside qualifying physics electives include 10-301, 11-485, and 15-388, but other options may be approved.

Additional Major or Dual Degree in Physics

Physics may be taken as an additional major (also known as a “double major”) or as a second degree, with another department granting the primary degree. The rules of the Physics Department for these two options are distinct, as discussed below.

Additional Major

In order to receive an Additional Major in Physics, with another department granting the primary degree — with a B.S. or B.A., alone or with any track — all requirements of the Physics degree and the particular physics track, as listed in the previous sections, must be fulfilled except:

- No STEM Electives are required
- No Non-Technical Electives are required
- 03-121 Modern Biology is not required

- 09-105 Introduction to Modern Chemistry I is not required
- No Free Electives are required

The full requirements are described below:

Physics Core:

All physics majors take these courses in physics, which are designed to teach the fundamentals required for any specialty. Many students take the 100-level courses in their first year of study, the 200-level courses in their second year, and the 300-level courses in their third or fourth year.

| | Units |
|--|------------|
| 33-121 Physics I for Science Students | 12 |
| or 33-151 Matter and Interactions I | |
| Corequisite for 33-121 is 21-120 | |
| 33-142 Physics II for Engineering and Physics Students | 12 |
| or 33-152 Matter and Interactions II | |
| 33-104 Experimental Physics | 9 |
| 33-201 Physics Sophomore Colloquium I | 2 |
| 33-211 Physics III: Modern Essentials | 10 |
| 33-231 Physical Analysis | 10 |
| 33-202 Physics Sophomore Colloquium II | 2 |
| 33-228 Electronics I | 10 |
| 33-232 Mathematical Methods of Physics | 10 |
| 33-234 Quantum Physics | 10 |
| 33-301 Physics Upperclass Colloquium I | 1 |
| 33-331 Physical Mechanics I | 10 |
| 33-338 Intermediate Electricity and Magnetism I | 10 |
| 33-341 Thermal Physics I | 10 |
| 33-302 Physics Upperclass Colloquium II | 1 |
| 33-340 Modern Physics Laboratory | 10 |
| Total Physics Core Units | 129 |

Mathematics Core:

All physics majors take these calculus courses from the Department of Mathematics to support their studies in physics.

| | Units |
|---|-----------|
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| 21-259 Calculus in Three Dimensions | 10 |
| Total Mathematics Core Units | 30 |

Technical Core for an Additional Major:

Students pursuing an additional major in physics do not need to fulfill the full Technical Core required by the Mellon College of Science, but are still required to take either 15-110 or 15-112 (or an equivalent course as pre-approved by the Associate Dean of Undergraduate Affairs, Mellon College of Science).

| | Units |
|--|--------------|
| 15-110 Principles of Computing | 10-12 |
| or 15-112 Fundamentals of Programming and Computer Science | |
| Total Technical Core Units | 10-12 |

Technical Electives for an Additional Major:

Students pursuing an additional major in physics must take the Physics Electives and Mathematics Elective required of physics as the primary major, but do not need to take the STEM electives. Students may choose these electives individually, but may opt to complete the requirements as part of the Physics Tracks (p. 662) described in the B.S. in Physics section. Students interested in completing an additional major with a track should consult with the Director of Undergraduate Affairs.

| | Units |
|---------------------------------------|--------------|
| 33-xxx Physics Breadth Elective | 9-12 |
| 33-xxx 3 Qualifying Physics Electives | 27-37 |
| 21-2xx Mathematics Elective | 9-10 |
| Total Technical Electives | 45-59 |

Dual Degree

In order to receive a Dual Degree in another subject and Physics, all requirements of the Physics degree must be fulfilled. Students may choose

to complete the B.A. or the B.S. in Physics, with or without a track. Students must complete both the technical and non-technical requirements, and should consult with the Director of Undergraduate Affairs for questions about double counting. The number of units required is 90 more than the total units required by the department requiring the fewer total units. Since Physics requires 360 units, the lowest possible minimum for a Dual Degree with Physics is 450 units.

Minor in Physics

The Minor in Physics is designed to provide a solid foundation in physics at the introductory level, followed by elective courses which will familiarize the student with areas of modern physics, and the concepts and techniques employed therein. The physics minor requires seven courses of at least 9 units each, of which four are required and three are electives.

The Minor is open to all students in the university, but students with non-calculus-based majors should be aware of the mathematics requirements for many physics courses (21-120, 21-122, and 21-259).

| | | Units |
|---|--|--------------|
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| or 33-151 | Matter and Interactions I | |
| Corequisite for 33-121 or 33-141 is 21-120 & for 33-151 is 21-122 | | |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 12 |
| or 33-142 | Physics II for Engineering and Physics Students | |
| or 33-152 | Matter and Interactions II | |
| Corequisite for 33-122 or 33-142 is 21-122 & for 33-152 is 21-259 | | |
| 33-104 | Experimental Physics | 9 |
| 33-211 | Physics III: Modern Essentials | 10 |
| 33-xxx | Three Qualifying Physics Electives or Physics Core Electives ²⁴ | 27-36 |
| Total Physics Minor Units | | 70-79 |

[24] The physics electives are decided after consultation with, and approval by, the Director of Undergraduate Affairs. Students may take courses from the Qualifying Physics List or additional courses from the Physics Core list, such as Quantum Physics or Electronics I.

Transfer Credit Requests

Requests for transfer credit for undergraduate physics classes should be made through the student's home college. Students should contact their departmental academic advisor for the transfer request process in their college. It is recommended that requests be placed before paying tuition for a class in case transfer credit is denied. Requests may take 1-2 weeks to be processed by the Department of Physics.

Criteria for Transfer

In assessing the suitability of courses for transfer credit, the Department of Physics will consider the following factors:

- The academic rigor of the course must be comparable to that offered at Carnegie Mellon University. This is usually assessed via the quality of the institution and its physics program, the course prerequisites and corequisites, the textbook used, and the amount of time spent on topic areas. Only courses from semester-based institutions will be considered for transfer a one-to-one basis. In general, the rate of approval is significantly higher for four-year institutions with science majors as opposed to community colleges. Completely online classes with no proctored examination do not meet our standard for transfer credit.
- The mathematical rigor of a course must also be comparable to that for the CMU course for which a transfer is requested. For example, a class that has no math prerequisite is unlikely to transfer as a CMU class for which there is such a prerequisite, and algebra-based Physics I or Physics II classes will not be accepted for transfer as our calculus-based courses.
- The topic areas of a given class and time devoted to each topic should match to a degree of at least 80% those covered in the comparable course at Carnegie Mellon University, although this criterion alone is not sufficient to merit transfer. Classes that meet this criterion may still be denied transfer credit if key topics are found to be excluded or if the above mentioned requirements regarding rigor are not met.

Requirements for Transfer Requests

The Department of Physics requires all the following materials to determine if transfer is recommended:

- Name of course and its home institution
- Number of credits/units/contact hours per week
- Course syllabus
- Official catalog course description and list of topics covered in the course
- A list of all prerequisite and corequisite courses, and official catalog course descriptions of these courses
- Required textbook (name, author, and link to information about the text required)

Transfer requests that do not include all information above will not be recommended.

Faculty

JOHN ALISON, Assistant Professor of Physics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2018–

DAVID ANDERSON, Associate Teaching Professor of Physics – Ph.D., University of York (UK) ; Carnegie Mellon, 2008–

SHILADITYA BANERJEE, Associate Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2020–

KATELYN BREIVIK, Assistant Professor of Physics – Ph.D., Northwestern University; Carnegie Mellon, 2023–

ROY A. BRIERE, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1999–

SHUBHAYU CHATTERJEE, Assistant Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 2023–

HAEL COLLINS, Assistant Teaching Professor of Physics – Ph.D., Harvard University; Carnegie Mellon, 2019–

MATTEO CREMONESI, Assistant Professor of Physics – Ph.D., Oxford University; Carnegie Mellon, 2022–

RUPERT CROFT, Professor of Physics – Ph.D., Oxford University; Carnegie Mellon, 2001–

MARKUS DESERNO, Professor of Physics; Director of Graduate Studies, Department of Physics – Ph.D., University of Mainz, Germany; Carnegie Mellon, 2007–

TIZIANA DI MATTEO, Professor of Physics – Ph.D., University of Cambridge; Carnegie Mellon, 2005–

SCOTT DODELSON, Professor of Physics; Head, Department of Physics – Ph.D., Columbia University; Carnegie Mellon, 2017–

VALENTINA DUTTA, Assistant Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

RANDALL M. FEENSTRA, Professor of Physics – Ph.D., California Institute of Technology; Carnegie Mellon, 1995–

FRANK HEINRICH, Associate Research Professor of Physics – Ph.D., University of Leipzig; Carnegie Mellon, 2008–

BENJAMIN HUNT, Associate Professor of Physics – Ph.D., Cornell University; Carnegie Mellon, 2015–

TINA KAHNIASHVILI, Associate Research Professor of Physics – Ph.D., Russian Academy of Sciences; Carnegie Mellon, 2010–

JYOTI KATOCH, Assistant Professor or Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

VLADYSLAV KOZII, Assistant Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2022–

BARRY B. LUOKKALA, Teaching Professor of Physics; Director of Undergraduate Laboratories, Department of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1988–

SARA A. MAJETICH, Professor of Physics – Ph.D., University of Georgia; Carnegie Mellon, 1990–

RACHEL MANDELBAUM, Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2011–

CURTIS A. MEYER, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

COLIN J. MORNINGSTAR, Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2000–

ANTONELLA PALMESE, Assistant Professor of Physics – Ph.D., University College London; Carnegie Mellon, 2022–

DIANA S. PARNO, Associate Professor of Physics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2017–

MANFRED PAULINI, Professor of Physics; Associate Dean, Mellon College of Science – Ph.D., University of Erlangen, Germany; Carnegie Mellon, 2000–

RICCARDO PENCO, Assistant Professor of Physics – Ph.D., Syracuse University; Carnegie Mellon, 2018–

JEFFREY B. PETERSON, Professor of Physics – Ph.D., University of California, Berkeley; Carnegie Mellon, 1993–

RACHEL ROSEN, Associate Professor of Physics – Ph.D., New York University; Carnegie Mellon, 2023–

IRA Z. ROTHSTEIN, Professor of Physics – Ph.D., University of Maryland at College Park; Carnegie Mellon, 1997–

GILLIAN LYNN RYAN, Associate Teaching Professor of Physics; Director of Undergraduate Affairs, Department of Physics – Ph.D., Dalhousie University; Carnegie Mellon, 2020–

REINHARD A. SCHUMACHER, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1987–

SUFEI SHI, Associate Professor of Physics – Ph.D., Cornell University; Carnegie Mellon, 2023–

FANGWEI SI, Assistant Professor of Physics – Ph.D., Johns Hopkins University; Carnegie Mellon, 2022–

SIMRANJEET SINGH, Assistant Professor of Physics – Ph.D., University of Central Florida; Carnegie Mellon, 2018–

GRIGORY TARNOPOLSKY, Assistant Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2021–

HY TRAC, Associate Professor of Physics – Ph.D., University of Toronto; Carnegie Mellon, 2010–

MATTHEW WALKER, Associate Professor of Physics – Ph.D., University of Michigan; Carnegie Mellon, 2013–

MICHAEL WIDOM, Professor of Physics – Ph.D., University of Chicago; Carnegie Mellon, 1985–

Emeriti Faculty

LUC BERGER, Professor of Physics, Emeritus – Ph.D., University of Lausanne, Switzerland; Carnegie Mellon, 1960–

ARNOLD ENGLER, Professor of Physics, Emeritus – Ph.D., University of Berne, Switzerland; Carnegie Mellon, 1962–

THOMAS A. FERGUSON, Professor of Physics, Emeritus – Ph.D., University of California at Los Angeles; Carnegie Mellon; Carnegie Mellon, 1985–

JOHN G. FETKOVICH, Professor of Physics, Emeritus – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1959–

GREGG B. FRANKLIN, Professor of Physics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1984–

STEPHEN GAROFF, Professor of Physics – Ph.D., Harvard ; Carnegie Mellon, 1988–

FREDERICK J. GILMAN, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1995–

RICHARD GRIFFITHS, Professor of Physics, Emeritus – Ph.D., University of Leicester, U.K.; Carnegie Mellon, 1996–

ROBERT GRIFFITHS, University Professor of Physics, Emeritus – Ph.D., Stanford University; Carnegie Mellon, 1962–

LEONARD S. KISSLINGER, Professor of Physics, Emeritus – Ph.D., Indiana University; Carnegie Mellon, 1969–

GEORGE KLEIN, Associate Teaching Professor of Physics – Ph.D., New York University; Carnegie Mellon, 1993–

ROBERT W. KRAEMER, Professor of Physics, Emeritus – Ph.D., Johns Hopkins University; Carnegie Mellon, 1965–

MICHAEL J. LEVINE, Professor of Physics, Emeritus – Ph.D., California Institute of Technology; Carnegie Mellon, 1968–

LING-FONG LI, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1974–

MATHIAS LOSCHE, Professor of Physics – Ph.D., Technical University of Munich; Carnegie Mellon, 2005–

JOHN F. NAGLE, Professor of Physics, Emeritus – Ph.D., Yale University; Carnegie Mellon, 1967–

BRIAN P. QUINN, Professor of Physics, Emeritus – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1988–

JAMES S. RUSS, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1967–

ROBERT F. SEKERKA, University Professor of Physics and Mathematics, Emeritus – Ph.D., Harvard ; Carnegie Mellon, 1969–

ROBERT M. SUTER, Professor of Physics, Emeritus – Ph.D., Clark University; Carnegie Mellon, 1981–

ROBERT H. SWENDSEN, Professor of Physics, Emeritus – Ph.D., University of Pennsylvania; Carnegie Mellon, 1984–

STEPHANIE TRISTRAM-NAGLE, Research Professor of Physics, Emerita – Ph.D., University of California, Berkeley; Carnegie Mellon, 1986–

NED S. VANDER VEN, Professor of Physics, Emeritus – Ph.D., Princeton University; Carnegie Mellon, 1961–

HELMUT VOGEL, Professor of Physics, Emeritus – Ph.D., University of Erlangen-Nuremberg; Carnegie Mellon, 1983–

Joint Appointments and Courtesy Appointments

SHELLEY ANNA, Professor of Chemical Engineering – Ph.D., Harvard University; Carnegie Mellon, 2003–

AXEL BRANDENBURG, Adjunct Professor of Physics – Ph.D., University of Helsinki; Carnegie Mellon, 2018–

SHIRLEY HO, Adjunct Associate Professor of Physics – Ph.D., Princeton University; Carnegie Mellon, 2012–

MOHAMMAD F. ISLAM, Associate Research Professor of Materials Science & Engineering – Ph.D., University of Pennsylvania; Carnegie Mellon, 2005–

NOA MAROM, Assistant Professor of Material Science and Engineering – Ph.D., Weizmann of Science; Carnegie Mellon, 2016–

MICHAEL E. MCHENRY, Professor of Materials Science and Engineering – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 1989–

CARL RODRIGUEZ, Adjunct Professor of Physics – Ph.D., Northwestern University; Carnegie Mellon, 2023–

ANTHONY D. ROLLETT, Professor of Materials Science & Engineering – Ph.D., Drexel University; Carnegie Mellon, 1995–

MAREK SKOWRONSKI, Professor of Material Science and Engineering – Ph.D., Warsaw University; Carnegie Mellon, 1988–

VENKAT VISWANATHAN, Assistant Professor of Mechanical Engineering – Ph.D., Stanford University; Carnegie Mellon, 2014–

HUAIYING ZHANG, Assistant Professor of Biological Sciences – Ph.D., McGill University; Carnegie Mellon, 2022–

JIAN-GANG ZHU, Professor of Electrical and Computer Engineering – Ph.D., University of California San Diego; Carnegie Mellon, 1997–

Department of Physics Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

33-100 Basic Experimental Physics

All Semesters: 6 units

This course provides students with a basic introduction to experimental physics. The content of the course and the particular experiments to be carried out are chosen to be especially useful for students who intend to work in the health sciences. Specific topics will range from mechanics to nuclear and atomic physics. This course is specifically geared toward pre-health students.

33-101 Physics First Year Seminar

Fall and Spring

Various seminars are offered that introduce first-year students to current topics of modern physics. These are mini courses that meet for half a semester. In the past, seminar topics have included: Science and Science Fiction, Astrophysics, Black Holes, Cosmology and Supernovae, Elementary Particles, and The Building Blocks of Matter. These seminars are open only to MCS first year students.

33-104 Experimental Physics

All Semesters: 9 units

This course provides first year students and sophomores with an introduction to the methods of experimental physics. Particular emphasis is placed on three aspects of experimentation: laboratory technique, including both the execution and the documentation of an experiment; data analysis, including the treatment of statistical and systematic errors and computer-aided analysis of experimental data; and written communication of experimental procedures and results. The concepts and skills for measurement and data analysis are acquired gradually through a series of experiments covering a range of topics from mechanics to nuclear and atomic physics.

33-114 Physics of Musical Sound

Spring: 9 units

An introduction to the physics and psychophysics of musical sound. Elementary physics of vibrating systems. Propagation of sound: traveling waves, reflection, and diffraction. Addition of waves: interference and beats. Anatomy of the ear and the perception of sound: loudness, pitch, and timbre. Standing waves and natural modes. Qualitative description of general periodic systems by Fourier analysis: the harmonic series and complex musical tones. The acoustics of musical instruments including percussion instruments, such as drums, bars, and struck and plucked strings; and instruments exhibiting self-sustained oscillations, including bowed strings, blown pipes, reeds, brasses, and singing. Intervals and consonance, musical scales, tuning and temperament. Basic room and auditorium acoustics. There are no formal prerequisites, but some previous musical experience will be useful.

33-115 Physics for Future Presidents

Fall: 9 units

Countless topics of social and political importance are intimately related to science in general and physics in particular. Examples include energy production, global warming, radioactivity, terrorism, and space travel. This course aims to provide key bits of knowledge based on which such issues can be discussed in a meaningful way, i.e., on the level of arguments and not just vague beliefs. We will cover an unusually wide range of topics, including energy, heat, gravity, atoms, radioactivity, chain reactions, electricity, magnetism, waves, light, weather, and climate. The course is open for all students at CMU.

33-120 Science and Science Fiction

Fall and Spring: 9 units

We will view and critique the science content in a selection of science fiction films, spanning more than 100 years of cinematic history, and from sci-fi TV shows from the past 50+ years. Guided by selected readings from current scientific literature, and aided by order-of-magnitude estimates and careful calculations, we will ponder whether the films are showing things which may fall into one of the following categories: Science fiction at the time of production, but currently possible, due to recent breakthroughs. Possible, in principle, but beyond our current technology. Impossible by any science we know. Topics to be covered include the future of the technological society, the physics of Star Trek, the nature of space and time, extraterrestrial intelligence, robotics and artificial intelligence, biotechnology and more. Success of this course will depend upon class participation. Students will be expected to contribute to discussion of assigned readings and problems, and to give brief presentations in class on assigned films.

33-121 Physics I for Science Students

Fall and Spring: 12 units

This calculus-based course combines the basic principles of mechanics with some quantum physics and relativity to explain nature on both a microscopic and macroscopic scale. The course will build models to describe the universe based on a small number of fundamental physics principles. Some simple computer modeling will be done to develop insight into the solving of problems using Newton's laws. Topics covered will include vectors, momentum, force, gravitation, oscillations, energy, quantum physics, center of mass motion, rotation, angular momentum, statistical physics, and the laws of thermodynamics. No computer experience is needed. Examples illustrating basic principles being presented will be taken from physics, chemistry, and biology. This course has a co-requisite of 21-120.

33-122 Physics II for Biological Sciences & Chemistry Students

Fall and Spring: 9 units

This is the second course in the introductory physics sequence for chemistry and biological science majors. The course will consist of eight portions covering (1) electrostatics and dynamics, (2) electrical circuits, (3) magnetism, (4) waves, (5) optics, (6) diffusive motion, and (7) hydrostatic forces and flow. Emphasis will be put on the application of the underlying physical principles in the study of biology and chemistry. This course has a co-requisite of 21-122.

Prerequisites: (21-120 and 33-121) or 33-151 or 33-141 or (21-120 and 33-111) or 33-131 or 33-106

33-124 Introduction to Astronomy

Fall: 9 units

Astronomy continues to enjoy a golden age of exploration and discovery. This course presents a broad view of astronomy, straightforwardly descriptive and without any complex mathematics. The goal of the course is to encourage non-technical students to become scientifically literate and to appreciate new developments in the world of science, especially in the rapidly developing field of astronomy. Subjects covered include the solar system, stars, galaxies and the universe as a whole. The student should develop an appreciation of the ever-changing universe and our place within it. Computer laboratory exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes will be used to study the sky. This course is specifically geared toward non-science/engineering majors.

33-141 Physics I for Engineering Students

Fall and Spring: 12 units

This is a first semester, calculus-based introductory physics course. Basic principles of mechanics and thermodynamics are developed. Topics include vectors, displacement, velocity, acceleration, force, equilibrium, mass, Newton's laws, gravitation, work, energy, momentum, impulse, torque and angular momentum, temperature, heat, equations of state, thermodynamic processes, heat engines, refrigerators, first and second laws of thermodynamics, and the kinetic theory of gases. This course has a co-requisite of 21-120.

33-142 Physics II for Engineering and Physics Students

Fall and Spring: 12 units

This is the second half of a two-semester calculus-based introductory physics sequence for engineering and physics students. Two fifths of the course covers electricity, including electrostatics and electric fields, Gauss' law, electric potential, and simple circuits. Two fifths cover magnetism, including magnetic forces, magnetic fields, induction and electromagnetic radiation. One fifth of the course covers mechanical waves (including standing and traveling waves, superposition, and beats) and electromagnetic waves (including mode of propagation, speed, and other properties). This course has a co-requisite of 21-122.

Prerequisites: 33-106 or 33-141 or (21-120 and 33-111) or 33-131 or 33-151 or (21-120 and 33-121)

33-151 Matter and Interactions I

Fall: 12 units

For students with a strong physics background who are interested in using calculus-based mechanics to learn about topics such as dark matter, particle physics, and quantum phenomena, Matter and Interactions I provides an excellent alternative to Physics for Science Students. This course places great emphasis on constructing and using physical models, with a special focus on computer modeling to solve problems. Throughout the course, both traditional analytics techniques and scientific computing will be used to solve mechanical problems going from planetary systems, spring-based systems and nuclear scattering. Topics covered include Newton's Laws, microscopic models of solids, energy, energy quantization, mass-energy equivalence, multi particle systems, collisions, angular momentum including quantized angular momentum, kinetic theory of gases and statistical mechanics. Students are encouraged to do an optional research project that will be presented at a departmental poster session at the end of the semester. This course has a co-requisite of 21-122.

Prerequisite: 21-120

33-152 Matter and Interactions II

Spring: 12 units

A more challenging alternative to 33-142, Physics II for Engineering and Physics Students. There is an emphasis on atomic-level description and analysis of matter and its electric and magnetic interactions. Topics include: Coulomb's law, polarization, electric field, plasmas, field of charge distributions, microscopic analysis of resistor and capacitor circuits, potential, macroscopic analysis of circuits, Gauss' law, magnetic field, atomic model of magnetism, Ampere's law, magnetic force, relativistic issues, magnetic induction with emphasis on non-Coulomb electric field, Maxwell's equations, electromagnetic radiation including its production and its effects on matter, re-radiation, interference. There will also be computer modeling, visualization and desktop experiments.

Prerequisites: (21-122 and 33-151) or (33-131 and 21-122)

33-201 Physics Sophomore Colloquium I

Fall: 2 units

This course (together with 33-202) is designed to give students an overview of the field of Physics and to help students make knowledgeable choices in both their academic and professional careers. We discuss several of the subfields of Physics in order to give students an understanding of the types of activities, from research to industrial applications, in each. Over the two semesters, we typically discuss six subfields in some detail with the goal of providing a minimal literacy in the relevant concepts and language. The course consists of one classroom lecture per week plus one hour per week of reading and/or problem solving.

33-202 Physics Sophomore Colloquium II

Spring: 2 units

This course is the second in a sequence (following 33-201) designed to give students an overview of the field of Physics and to help students make knowledgeable choices in both their academic and professional careers. We discuss several of the sub-fields of Physics in order to give students an understanding of the types of activities, from research to industrial applications, in each. Over the two semesters, we typically discuss six subfields in some detail with the goal of providing a minimal literacy in the relevant concepts and language. The course consists of one classroom lecture per week plus one hour per week of reading and/or problem solving.

33-211 Physics III: Modern Essentials

Fall and Spring: 10 units

Physics III is primarily for third-semester students of physics, including all physics majors, but is open to any qualified student who wants an introduction to the physics of the 20th century. The course will have a strong component of Special Relativity, dealing with kinematics and dynamics, but not electricity and magnetism. (See 33-213 description.) It will introduce students to a conceptual theory, which is mathematically simple but (initially) non-intuitive. The course also provides a broad exposure to quantum phenomena and early quantum theory without getting overly mathematical. It leads into the more formal Quantum Physics course (33-234).

Prerequisites: 33-142 or 33-152 or 33-122 or 33-132 or 33-112 or 33-107

33-213 Mini-Course in Special Relativity

Fall and Spring: 4 units

This course spans the first six weeks of 33-211, Physics III: Modern Essentials and should not be taken by students intending to major in physics. It treats the mechanics aspects of special relativity, including topics such as simultaneity, the Lorentz transformation, time dilation, length contraction, space-time geometry, resolving some famous puzzles, and the momentum, mass, and energy relations. The Electricity and Magnetism portions of the subject are deferred until the junior/senior courses in E and amp;M (33-338/33-339). Students may not take this class if they have successfully completed 33-211.

Prerequisites: 33-152 or 33-122 or 33-142 or 33-112 or 33-132 or 33-107

33-224 Stars, Galaxies and the Universe

Fall: 9 units

The study of astronomy has blossomed over the past few decades as a result of new ground-based and space-based telescopes, and with the advantage of fast computers for analysis of the huge quantities of data. As our astronomical horizon expands, we are still able to use the laws of physics to make sense of it all. This course is for students who want to understand the basic concepts in astronomy and what drives astronomical objects and the universe. The course emphasizes the application of a few physical principles to a variety of astronomical settings, from stars to galaxies to the structure and evolution of the universe. Introductory classical physics is required, but modern physics will be introduced as needed in the course. The course is intended for science and engineering majors as well as students in other disciplines with good technical backgrounds. Computer lab exercises will be used to gain practical experience in astronomical techniques. In addition, small telescopes are available for personal sign-out for those who would like to use them, and outdoor observing sessions will be organized as weather permits.

Prerequisites: 33-131 or 33-141 or 33-151 or 33-121 or 33-106 or 33-111

33-225 Quantum Physics and Structure of Matter

Fall: 9 units

This course introduces the basic theory used to describe the microscopic world of electrons, atoms, and photons. The duality between wave-like and particle-like phenomena is introduced along with the deBroglie relations which link them. We develop a wave description appropriate for quanta which are partially localized and discuss the interpretation of these wavefunctions. The wave equation of quantum mechanics is developed and applied to the hydrogen atom from which we extrapolate the structure of the Periodic Table. Other materials-related applications are developed, for example, Boltzmann and quantum statistics and properties of electrons in crystals. This course is intended primarily for non-physics majors who have not taken 33-211.

Prerequisites: 33-112 or 33-107 or 33-142 or 33-152 or 33-132 or 33-122

33-226 Physics of Energy

Spring: 9 units

This course will apply basic science, in particular introductory physics concepts, to a wide variety of topics related to energy. The course will closely follow a widely praised textbook *The Physics of Energy*, so be divided into 3 parts: basic energy science; energy sources; and climate. This course fills the breadth requirement for Physics Majors or can be used as one of the 4 electives required for the Applied Physics Track.

Prerequisites: 33-152 or 33-122 or 33-142

33-228 Electronics I

Spring: 10 units

An introductory laboratory and lecture course with emphasis on elementary circuit analysis, design, and testing. We start by introducing basic circuit elements and study the responses of combinations to DC and AC excitations. We then take up transistors and learn about biasing and the behavior of amplifier circuits. The many uses of operational amplifiers are examined and analyzed; general features of feedback systems are introduced in this context. Complex functions are used to analyze all of the above linear systems. Finally, we examine and build some simple digital integrated circuits.

Prerequisites: 33-122 or 33-152 or 33-142 or 33-132 or 33-107 or 33-112

33-231 Physical Analysis

Fall: 10 units

This course aims to develop analytical skills and mathematical modeling skills across a broad spectrum of physical phenomena, stressing analogies in behavior of a wide variety of systems. Specific topics include dimensional analysis and scaling in physical phenomena, exponential growth and decay, the harmonic oscillator with damping and driving forces, linear approximations of nonlinear systems, coupled oscillators, and wave motion. Necessary mathematical techniques, including differential equations, complex exponential functions, matrix algebra, and Taylor series, are introduced as needed.

Prerequisites: 21-122 and (33-142 or 33-122 or 33-152)

33-232 Mathematical Methods of Physics

Spring: 10 units

This course introduces, in the context of physical systems, a variety of mathematical tools and techniques that will be needed for later courses in the physics curriculum. Topics will include linear algebra, Fourier series and transforms, vector calculus with physical applications, and a first look at partial differential equations. The techniques taught here are useful in more advanced courses such as Physical Mechanics, Electricity and Magnetism, and Advanced Quantum Physics.

Prerequisite: 33-231

33-234 Quantum Physics

Spring: 10 units

An introduction to the fundamental principles and applications of quantum physics. A brief review of the experimental basis for quantization motivates the development of the Schrodinger wave equation. Several unbound and bound problems are treated in one dimension. The properties of angular momentum are developed and applied to central potentials in three dimensions. The one electron atom is then treated. Matrix description of quantum physics and the notion of spin are introduced. Properties of collections of indistinguishable particles are developed allowing an understanding of the structure of the Periodic Table of elements. A variety of mathematical tools are considered as needed.

Prerequisite: 33-211

33-241 Introduction to Computational Physics

Fall: 9 units

This undergraduate course will provide an introduction to the numerical methods and computational algorithms used to solve a variety of problems in physics. In introductory physics courses, you are able to derive analytical solutions for simpler problems and often with simplifying assumptions. Have you wondered if a numerical solution can be obtained for a more complex problem that has no closed-form analytical solution? Computational physics provides a modern and powerful approach to complement classical approaches to problem solving. Today's and tomorrow's scientists must be computationally fluent to be competitive and successful. In this course, you will learn to formulate problems by applying physical principles, select and apply numerical methods, develop and apply computational algorithms, solve physical problems analytically and numerically, and visualize quantitative results using plotting software.

Prerequisites: 15-112 and 21-122 and 33-104 and (33-132 or 33-107 or 33-112 or 33-152 or 33-122 or 33-142)

33-301 Physics Upperclass Colloquium I

Fall: 1 unit

Junior and senior Physics majors meet together for 1 hour a week to hear discussions on current physics research from faculty, undergraduate and graduate students, and outside speakers. Other topics of interest such as application to graduate school, areas of industrial research and job opportunities will also be presented.

33-302 Physics Upperclass Colloquium II

Spring: 1 unit

Continuation of 33-301: Junior and senior Physics majors meet together for 1 hour a week to hear discussions on current physics research from faculty, undergraduate and graduate students, and outside speakers. Other topics of interest such as application to graduate school, areas of industrial research and job opportunities will also be presented.

33-331 Physical Mechanics I

Fall: 10 units

Fundamental concepts of classical mechanics. Conservation laws, momentum, energy, angular momentum, Lagrange's and Hamilton's equations, motion under a central force, scattering, cross section, and systems of particles.

Prerequisites: 21-259 and 33-232

33-332 Physical Mechanics II

Spring: 10 units

This is the second semester of a two-semester course on classical mechanics. The course will use the tools developed in 33-331 to examine motion in non-inertial reference frames; in particular, rotating frames. This then leads to the development of general rigid body motion, Euler's Equations. Finally, the course will cover coupled oscillations with particular emphasis on normal modes.

Prerequisite: 33-331

33-338 Intermediate Electricity and Magnetism I

Fall: 10 units

This course includes the basic concepts of electro- and magnetostatics. In electrostatics, topics include the electric field and potential for typical configurations, work and energy considerations, the method of images and solutions of Laplace's Equation, multipole expansions, and electrostatics in the presence of matter. In magnetostatics, the magnetic field and vector potential, magnetostatics in the presence of matter, properties of dia-, para- and ferromagnetic materials are developed.

Prerequisites: 21-259 and 33-232

33-339 Intermediate Electricity and Magnetism II

Spring: 10 units

This course focuses on electro- and magnetodynamics. Topics include Faraday's Law of induction, electromagnetic field momentum and energy, Maxwell's equations and electromagnetic waves including plane waves, waves in non-conducting and conducting media, reflection and refraction of waves, and guided waves. Electromagnetic radiation theory includes generation and characteristics of electric and magnetic dipole radiation. The Special Theory of Relativity is applied to electrodynamic: electric and magnetic fields in different reference frames, Lorentz transformations, four-vectors, invariants, and applications to particle mechanics.

Prerequisite: 33-338

33-340 Modern Physics Laboratory

Spring: 10 units

Emphasis is on hands-on experience observing important physical phenomena in the lab, advancing the student's experimental skills, developing sophisticated data analysis techniques, writing thorough reports, and improving verbal communication through several oral progress reports given during the semester and a comprehensive oral report on one experiment. Students perform three experiments which are drawn from the areas of atomic, condensed matter, classical, and nuclear and particle physics. Those currently available are the following: Zeeman effect, light scattering, optical pumping, thermal lensing, Raman scattering, chaos, magnetic susceptibility, nuclear magnetic resonance, electron spin resonance, X-ray diffraction, M and #246;sbauer effect, neutron activation of radioactive nuclides, Compton scattering, and cosmic ray muons.

Prerequisites: 33-234 and (33-341 or 33-338 or 33-331)

33-341 Thermal Physics I

Fall: 10 units

The three laws of classical thermodynamics, which deal with the existence of state functions for energy and entropy and the entropy at the absolute zero of temperature, are developed along phenomenological lines. Elementary statistical mechanics is then introduced via the canonical ensemble to understand the interpretation of entropy in terms of probability and to calculate some thermodynamic quantities from simple models. These laws are applied to deduce relationships among heat capacities and other measurable quantities and then are generalized to open systems and their various auxiliary thermodynamic potentials; transformations between potentials are developed. Criteria for equilibrium of multicomponent systems are developed and applied to phase transformations and chemical reactions. Models of solutions are obtained by using statistical mechanics and are applied to deduce simple phase diagrams for ideal and regular solutions. The concept of thermodynamic stability is then introduced and illustrated in the context of phase transformations.

Prerequisites: 33-234 and 33-232

33-342 Thermal Physics II

Spring: 10 units

This course begins with a more systematic development of formal probability theory, with emphasis on generating functions, probability density functions and asymptotic approximations. Examples are taken from games of chance, geometric probabilities and radioactive decay. The connections between the ensembles of statistical mechanics (microcanonical, canonical and grand canonical) with the various thermodynamic potentials is developed for single component and multicomponent systems. Fermi-Dirac and Bose-Einstein statistics are reviewed. These principles are then applied to applications such as electronic specific heats, Einstein condensation, chemical reactions, phase transformations, mean field theories, binary phase diagrams, paramagnetism, ferromagnetism, defects, semiconductors and fluctuation phenomena. This course is offered in Spring of odd years (e.g. Spring '23, '25, etc.)

Prerequisite: 33-341

33-350 Undergraduate Research

Fall and Spring

Open to sophomore, junior, and senior physics majors. The student undertakes a project of interest under the supervision of a faculty member for 3 to 9 units of credit. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. Student should contact faculty directly to inquire about opportunities. Registration requires approval of the Director of Undergraduate Affairs.

33-353 Intermediate Optics

Fall: 12 units

Offered alternative years. Geometrical optics: reflection and refraction, mirrors, prisms, lenses, apertures and stops, simple optical instruments, fiber optics. Scalar wave optics: wave properties of light, interference, coherence, interferometry, Huygens-Fresnel principle, Fraunhofer diffraction, resolution of optical instruments, Fourier optics, Fresnel diffraction. Laser beam optics: Gaussian beams. Vector wave optics: electromagnetic waves at dielectric interfaces, polarized light. The course will use complex exponential representations of electromagnetic waves.

Prerequisites: 33-107 or 33-122 or 33-152 or 33-142 or 33-112 or 33-132

33-355 Nanoscience and Nanotechnology

Fall: 9 units

Offered alternative years. This course will explore the underlying science behind nanotechnology, the tools used to create and characterize nanostructures, and potential applications of such devices. Material will be presented on a level intended for upper-level science and engineering students. The course will start with a survey of physics at different length scales, and introduce the application of elementary quantum mechanics and solid-state physics to nanoscience and nanotechnology. Characterization using electron microscopy, scanning probe methods, and spectroscopic techniques will then be described in detail. Fabrication using top-down and bottom-up methods will be discussed, contrasting these approaches and providing examples of each. Nanotechnology methods will be compared with those used in the modern microelectronics industry. Finally, examples of nanoscale components and systems will be described, which may include semiconductor heterostructures; nanotubes and graphene; single-electron transistors; nanoscale magnetic devices; photonic devices; nanofluidic devices; nano electrical-mechanical systems (NEMS); and superconducting devices. There will be time allocated to other topics, with the mutual agreement of the instructor and the class. Stand-alone laboratory exercises will be included as an important element of the course. These will focus on the use of scanning probe methods to study the nm-scale structure and atomic forces involved in various nanostructures as well as micro-scale patterning using photolithography. In addition to the prerequisites, students should have taken a prior laboratory course in a science or engineering department and should have some familiarity with differential equations at an elementary level.

Prerequisites: 33-234 or 33-225

33-398 Special Topics

Fall: 9 units

The description of most all physical systems relies on the concept of a manifold. In addition to the space-time manifold, which plays the role of the stage upon which the dynamics plays out, many systems involve target spaces which are manifolds. These target spaces are typically Lie Groups. A classic example of such a system is the rigid rotator, where every configuration of the system is a point on the manifold which defines the group of rotations. The purpose of this class will be to learn the basics of differential geometry and apply these ideas to physical systems. Topics will include Hamiltonian dynamics, fluid mechanics as well as gauge theories. Requirements: Knowledge of Linear Algebra. No prior knowledge of group theory will be expected.

Prerequisites: (33-231 or 21-260) and 21-341

33-441 Introduction to Biophysics

Fall: 10 units

Biological physics, or the physics of living systems, is an exciting interdisciplinary frontier of physics that aims to understand the phenomenon of life using concepts and tools from Physics. This intermediate level course will introduce the general concepts and principles underpinning the physical behavior of living systems, from the dynamics of proteins and molecules to collective behavior of living cells and organisms. The course will develop key physics concepts that are most vital to biological processes, including energy conversion, information transfer, mechanics of movement, statistical phenomena, and fluid flow. We will apply these physics concepts to demonstrate how biological systems function, build simplified mathematical models to predict behavior, and use experimental data to inform and test models. The integration of biological phenomena, physical concepts, mathematical modeling, and analysis of experimental data represents an entirely new mode of learning, based on strategies adopted in research. These strategies will break traditional disciplinary barriers between physics and biology. The students will be expected to gain an intuitive grasp of ways to: frame the physical problem, identify appropriate theoretical frameworks, analyze experimental data, and ways to generalize and to understand the dependence of biophysical phenomenon on time and length scales. No prior knowledge of biology is expected. This class is offered in Fall of even years (e.g. Fall '22, 24, etc.) Prerequisites: 33-142 or 33-122 or 33-132 or 33-107 or 33-152 or 33-112

33-444 Introduction to Nuclear and Particle Physics

Spring: 9 units

Description of our understanding of nuclei, elementary particles, and quarks, with equal emphasis on the nuclear and particle aspects of sub-atomic matter. We discuss the physics of accelerators, and how particle interactions with matter lead to various kinds of detector instrumentation. Then we discuss methods for measuring sub-atomic structure, symmetries and conservation laws, and the electromagnetic, weak, and strong interactions. We examine the quark model of the mesons and baryons, as well as several models of the atomic nucleus.

Prerequisites: 33-234 and 33-338

33-445 Advanced Quantum Physics I

Fall: 9 units

Mathematics of quantum theory, linear algebra and Hilbert spaces; review of classical mechanics; problems with classical mechanics; postulates of quantum theory; one dimensional applications; the harmonic oscillator; uncertainty relations; systems with N degrees of freedom, multi-particle states, identical particles; approximation methods. This course has a co-requisite of 33-331.

Prerequisite: 33-234

33-446 Advanced Quantum Physics II

Spring: 9 units

Classical symmetries; quantum symmetries; rotations and angular momentum; spin; addition of angular momentum; the hydrogen atom; quantum "paradoxes" and Bell's theorem; applications.

Prerequisite: 33-445

33-448 Introduction to Solid State Physics

Spring: 9 units

This course gives a quantitative description of crystal lattices, common crystal structures obtained by adding a basis of atoms to the lattice, and the definition and properties of the reciprocal lattice. Diffraction measurements are studied as tools to quantify crystal lattices, including Bragg's law and structure factors. Diffraction from amorphous substances and liquids is also introduced. The various types of atomic bonding, e.g., Van der Waals, metallic, ionic, covalent and hydrogen are surveyed. Binding energies of some crystalline structures are calculated. Models of crystal binding are generalized to include dynamics, first for classical lattice vibrations and then for quantized lattice vibrations known as phonons. These concepts are used to calculate the heat capacities of insulating crystals, to introduce the concept of density of states, and to discuss phonon scattering. The band theory of solids is developed, starting with the free electron model of a metal and culminating with the properties of conductors and semiconductors. Magnetic phenomena such as paramagnetism and the mean field theory of ferromagnetism are covered to the extent that time permits.

Prerequisites: 33-341 and (33-234 or 33-225)

33-451 Senior Research

Fall and Spring

Open to all senior physics majors. May include research done in a research lab, extending the capabilities of a teaching lab, or a theoretical or computational physics project for 3 to 9 units of credit. The student experiences the less structured atmosphere of a research program where there is much room for independent initiative. Modern Physics Laboratory, 33-340, should precede this course, though it is not required. Student should contact faculty directly to inquire about opportunities. Registration requires approval of the Director of Undergraduate Affairs.

33-456 Advanced Computational Physics

Spring: 9 units

This course uses techniques covered in Introduction to Computational Physics as a foundation. Major topics in the course will be Data Science, Parallel Computing and Machine Learning with applications from astrophysics, thermodynamics, orbital mechanics and other domains. The course will introduce professional practices such as compiling and optimizing code, using software development environments and software engineering. Students will gain a practical knowledge of current computing hardware design, the C computer language, the TensorFlow deep learning framework and the Spark big data platform, while using a Linux supercomputing environment.

Prerequisite: 33-241

33-466 Extragalactic Astrophysics and Cosmology

Spring: 9 units

Starting from the expanding universe of galaxies, this course lays out the structure of the universe from the Local Group of galaxies to the largest structures observed. The observational pinnacle of the Big Bang theory, the microwave background radiation, is shown to provide us with many clues to conditions in the early universe and to the parameters which control the expansion and fate of the universe. Current theories for the development of galaxies and clusters of galaxies are outlined in terms of our current understanding of dark matter. Observational cosmology continues to enjoy a golden era of discovery and the latest observational results will be interpreted in terms of the basic cosmological parameters.

Prerequisites: 33-224 and 33-234

33-467 Astrophysics of Stars and the Galaxy

Fall: 9 units

The physics of stars is introduced from first principles, leading from star formation to nuclear fusion to late stellar evolution and the end points of stars: white dwarfs, neutron stars and black holes. The theory of stellar structure and evolution is elegant and impressively powerful, bringing together all branches of physics to predict the life cycles of the stars. The basic physical processes in the interstellar medium will also be described, and the role of multi-wavelength astronomy will be used to illustrate our understanding of the structure of the Milky Way Galaxy, from the massive black hole at the center to the halo of dark matter which encompasses it.

Prerequisites: 33-224 and 33-234

33-499 Supervised Reading

Fall and Spring

Physics majors may explore a certain area of advanced physics under the direct supervision of a faculty member for up to 9 units of credit. Special permission is required from the Director for Undergraduate Affairs to register. The student must contact a faculty member directly to inquire about opportunities, and to develop a written plan that includes a list of topics to be covered, expectations of student time and/or work, as well as a description of how student learning will be evaluated. The Director of Undergraduate Affairs will review this plan and students will be registered only if the plan is approved.

33-650 General Relativity

Fall: 9 units

General Relativity is the classical theory of gravity. It is widely recognized as a beautiful theory - equating gravity and the geometry of spacetime leads to a profound conceptual change in the way we regard the universe. The predictions of the theory are relevant to systems as varied as high precision measurements of the earth's gravitational field or the strongly curved space-times around black holes. In this course, we will gradually develop an understanding of the geometries which are the solutions of the Einstein equation, with an emphasis on their relevance to physical situations. We will motivate the theory step by step and eventually introduce the Einstein equation itself.

Prerequisites: 33-211 and 33-339

33-658 Quantum Computation and Quantum Information Theory

Fall: 10 units

This course provides an overview of recent developments in quantum computation and quantum information theory. The topics include: a review of relevant concepts in quantum mechanics and in information theory. It will then cover quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shors factorization algorithm, Grovers search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. It will also include hands-on experience running programs on cloud quantum computers.

Prerequisite: 33-234 Min. grade B

33-659 Quantum Hall Effect and Topological Insulators

Intermittent: 12 units

This course will introduce students to the topic of topological insulators and related phenomena using the Berry phase a unifying concept. In the first half of the semester, we will cover basic concepts such as Berry phase, Dirac fermions, Hall conductance and its link to topology, and the Hofstadter problem of lattice electrons in a magnetic field. Linear response theory will be discussed in relation to the Hall conductance. In the second half, we will move on to explain topological phases of matter such as Chern insulators and two- and three-dimensional topological insulators. Various techniques to calculate the topological indices will be introduced and connection to real materials will be discussed. Numerical studies of various tight-binding models provide intuitive understandings and will be an essential part of this course.

Prerequisite: 33-448

33-755 Quantum Mechanics I

Fall: 12 units

This course introduces fundamental concepts of quantum mechanics. Applications are made to quantum computing, the harmonic oscillator, the hydrogen atom, electron spin and addition of angular momentum.

Prerequisite: 33-446

33-756 Quantum Mechanics II

Spring: 12 units

This course focuses on qualitative and approximation methods in quantum mechanics, including time-independent and time-dependent perturbation theory, scattering and semiclassical methods. Applications are made to atomic, molecular and solid matter. Systems of identical particles are treated including many electron atoms and the Fermi gas. Prerequisite: 33-755, Quantum Mechanics I; 33-759 Theoretical Physics. 3 hrs. lecture. Typical Text: Cohen-Tannoudji Quantum Mechanics, volume 2. Prerequisites: 33-755 and 33-759

33-758 Quantum Computation and Quantum Information Theory

Spring: 12 units

This course, taught in collaboration with the Computer Science Department, provides an overview of recent developments in quantum computation and quantum information theory. The topics include: an introduction to quantum mechanics, quantum channels, both ideal and noisy, quantum cryptography, an introduction to computational complexity, Shor's factorization algorithm, Grover's search algorithm, and proposals for the physical realization of quantum devices, such as correlated photons, ions in traps, and nuclear magnetic resonance. The textbook is Nielsen and Chuang, Quantum Computation and Quantum Information. 3 hrs. lecture plus weekly seminar. A 10 unit version of the course, 33-658, does not include the seminar.

33-759 Introduction to Mathematical Physics I

Fall: 12 units

This course is an introduction to methods of mathematical analysis used in solving physical problems. Emphasis is placed both upon the generality of the methods, through a variety of sample problems, and upon their underlying principles. Topics normally covered include matrix algebra (normal modes, diagonalization, symmetry properties), complex variables and analytic functions, differential equations (Laplace's equation and separation of variables, special functions and their analytic properties), orthogonal systems of functions. Prerequisite: 33-232

33-761 Classical Electrodynamics I

Fall: 12 units

This course deals with the static and dynamic properties of the electromagnetic field as described by Maxwell's equations. Among the topics emphasized are solutions of Laplace's, Poisson's and wave equations, effects of boundaries, Green's functions, multipole expansions, emission and propagation of electromagnetic radiation and the response of dielectrics, metals, magnetizable bodies to fields. Prerequisite: 33-339

33-762 Classical Electrodynamics II

Spring: 12 units

The applications of electromagnetic theory to various physical systems is the main emphasis of this course. The topics discussed include the theory of wave guides, scattering of electromagnetic waves, index of refraction, special relativity and foundation of optics. 3 hrs. lecture. Typical Text: Jackson, Classical Electrodynamics. 2nd Ed.

33-765 Statistical Mechanics

Spring: 12 units

This course develops the methods of statistical mechanics and uses them to calculate observable properties of systems in thermodynamic equilibrium. Topics treated include the principles of classical thermodynamics, canonical and grand canonical ensembles for classical and quantum mechanical systems, partition functions and statistical thermodynamics, fluctuations, ideal gases of quanta, atoms and polyatomic molecules, degeneracy of Fermi and Bose gases, chemical equilibrium, ideal paramagnetics and introduction to simple interacting systems. 3 hrs. lecture, 1 hr. recitation. Typical Texts: Swendsen, An Introduction to Statistical Mechanics and Thermodynamics; Kardar, Statistical Physics of Particles; McQuarrie, Statistical Mechanics

33-767 Biophysics: From Basic Concepts to Current Research

Spring: 12 units

This course mixes lectures and student presentations on advanced topics in Biological Physics. In the course, students will gain a deep appreciation of the fact that very basic physical and chemical principles underly many central life processes. Life is not only compatible with the laws of physics and chemistry, rather, it exploits them in ingenious ways. After taking the course, students should be able to name examples of such situations for which they can provide a coherent line of reasoning that outlines these connections. They will be able to explain key experiments by which these connections either have been found or are nowadays routinely established, and outline simple back-of-the-envelope estimates by which one can convince oneself of either the validity or inapplicability of certain popular models and ideas. They should also have become sufficiently familiar with the key terminology frequently encountered in biology, such that they can start to further educate themselves by consulting biological and biophysical literature. The course uses Physical Biology of the Cell by Rob Phillips et al. (Garland Science, New York, NY, 2013, ISBN 978-0-8153-4450-6).

33-769 Quantum Mechanics III: Many Body and Relativistic Systems

Fall: 12 units

The first main theme of this course is quantum mechanics applied to selected many-body problems in atomic, nuclear and condensed matter physics. The second main theme is relativistic quantum mechanics. Creation and annihilation operators are introduced and used to discuss Hartree-Fock theory as well as electromagnetic radiation. The Dirac equation is introduced and applied to the hydrogen atom. Prerequisite: 33-756, 33-761. 3 hrs. lecture Prerequisites: 33-761 and 33-756

33-770 Field Theory I

Fall: 12 units

This course gives systematic studies of the relativistic field theories. Topics included are canonical quantization of fields, LSZ reduction formula, Feynman diagram techniques, application to quantum electrodynamics and the discussion of the methods of renormalization. Prerequisite: 33-756

33-771 Field Theory II

All Semesters: 12 units

Missing Course Description - please contact the teaching department.

33-775 Introduction to Research 1

Fall: 12 units

Both semesters are designed to give the student opportunity to gain experience in modern experimental techniques either through participation in research laboratories or through formal instruction, depending on the student's background. In the first semester, the student will also learn of the research of the department through lectures by the faculty on their work. All students are required to take the first semester, but those with post-graduate or unusual laboratory experience may not be required to take the second. However, it should be noted that for the M.S. degree, 12 units of laboratory are required.

33-777 Introductory Astrophysics

Fall: 12 units

Introductory Astrophysics is survey course with a mix of observational and theoretical investigations into astrophysical systems across a range of scales, covering planetary physics (solar system and extrasolar planets), stellar structure/evolution, Milky Way, extragalactic astrophysics, and cosmology.

33-778 Introduction to Cosmology

Fall: 12 units

An introduction to modern cosmology that includes detailed description of the smooth expanding universe (e.g., nucleosynthesis, the cosmic microwave background, and dark matter) and the perturbations that translate into the large scale structure of the universe. Prerequisites: 33-234 and 33-232

33-779 Introduction to Nuclear and Particle Physics

Fall: 12 units

An introduction to the physics of atomic nuclei and elementary particles. This course is suitable as a one-semester course for students not specializing in this area and also provides an introduction to further work in 33-780, 33-781. Topics included are symmetry principles of strong and weak interactions, quark model, classification of particles and nuclear forces.

33-780 Nuclear and Particle Physics II

Spring: 12 units

This course covers the phenomenology of weak interactions, parton model for the deep inelastic scattering, and introduction to gauge theories of weak and electromagnetic interactions. Various topics of current interest in particle physics will also be included. Prerequisite: 33-779, 33-770 (or concurrently). 3 hrs. lecture.

Prerequisites: 33-779 and 33-770

33-783 Solid State Physics

Fall: 12 units

This course is designed to give advanced graduate students a fundamental knowledge of the microscopic properties of solids in terms of molecular and atomic theory, crystal structures, x-ray diffraction of crystals and crystal defects, lattice vibration and thermal properties of crystals; free-electron model, energy bands, electrical conduction and magnetism.

Prerequisite: 33-756 Min. grade B

MCS Interdisciplinary Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

38-100 CATALYST - MCS First-Year Seminar

Fall and Spring: 3 units

The CATALYST seminar will equip transfer students to MCS, as well as those students who did not successfully complete the EUREKA seminar, with foundational knowledge, skills and perspectives that will support their development as emerging scientists and scholars. During the seminar, students will be presented with opportunities and experiences designed to help them frame how the MCS curriculum aspires to shape their evolving identities in the areas of scholar, person, professional and citizen, while also engendering a sense of excitement about science and scientific inquiry. The seminar will offer information and strategies that are employed both by successful students and by successful scientists in optimizing their approach to work and life, with a key focus on areas such as cognitive learning skills, research, teamwork, goal setting, time management, community engagement, ethics, resources and assessment. Additionally, the seminar will introduce students to the learning outcomes and requirements associated with the MCS core curriculum, with a particular emphasis on the self-directed ENGAGE courses and the role of the MyCORE e-portfolio system in documenting and framing student growth and development.

38-101 EUREKA!: Discovery and Its Impact

Fall: 6 units

The MCS first-year seminar "EUREKA: Discovery and Its Impact" will equip new students with foundational knowledge, skills and perspectives that will support their development as emerging scientists. During the seminar, students will be presented with opportunities and experiences designed to help them frame how the MCS curriculum aspires to shape their evolving identities in the areas of scholar, person, professional and citizen, while also engendering a sense of excitement about science and scientific inquiry. The seminar will offer information and strategies that are employed both by successful students and by successful scientists in optimizing their approach to work and life, with a key focus on areas such as cognitive learning skills, research, teamwork, goal setting, time management, innovation, community engagement, ethics, resources and assessment. Additionally, the seminar will introduce first-year students to the learning outcomes and requirements associated with the MCS core curriculum, with a particular emphasis on the self-directed ENGAGE courses and the role of the e-portfolio system in documenting and framing student growth and development.

38-110 ENGAGE in Service

Fall and Spring: 1 unit

ENGAGE in Service is a 1-unit course (9 hours of work, minimum requirement for a passing grade) designed to promote MCS students' direct engagement with community development and service learning. To fulfill this requirement, students must engage in a minimum of 9 hours of work devoted to a non-profit organization or organizations of their choice, 3 of which must have a direct benefit to the local Pittsburgh community. Students may complete the requirements anytime during their undergraduate years, but must register for the class during the semester that they intend to complete it, no later than their penultimate semester. Coursework includes documentation of service via completion of a form for each eligible activity that includes a time log, a description of the activity, the name and contact information for their supervisor and the supervisor's signature. In addition, during the last semester of the project/course students will prepare a 1-2 page reflective paper on the lessons learned from their immersion in the organization(s) and its (their) work. No pay or other compensation can be received, and, in special cases, students may petition for a waiver if they have completed another service-learning course at Carnegie Mellon.

38-132 DC Grand Challenge First-Year Seminar: Health in Unhealthy Times: Preventing, Ma

Intermittent: 9 units

We live in times when health is a major global concern, whether we worry about the development of novel Covid-19 mutations or continue to grapple with chronic illnesses such as obesity, diabetes, autoimmune diseases, cancer as well as depression and anxiety. Health and illness are key drivers of the human experience. And yet, health is fundamentally impacted by different human experiences. This first year Grand Challenges seminar will introduce students to core concepts in the life sciences that will enable them to better appreciate the scientific aspects of health. Building on this knowledge, students will then explore important psychosocial determinants, ethical constraints, and historical roots of health. Students will also develop a familiarity with the cultural and communicative skills required to argue about health, make decisions, and engage empathically with others in their health stories. We will read and discuss a broad variety of materials from medical science articles to social psychological experimental reports and personal or literary narratives about health. The course is divided into three components: health and preventative behaviors; coping with disruptive health experiences; managing chronic health challenges. We will provide a broad overview for each category, followed by a deep dive focused on particular health issues: diet and exercise (prevention); anxiety and depression (management); epidemics/Covid-19/cancer (disruption). Given the broad array of topics discussed, we believe these components can engage students on a personal level.

38-220 ENGAGE in the Arts

Fall and Spring: 2 units

ENGAGE in the Arts is part of Mellon College of Science's Core Curriculum. In this 2-unit full-semester course, students will broaden their knowledge of the fine arts, extend their global and cultural awareness, and facilitate the further development of their self-identity. Coursework requires that students attend 8 distinct arts events, 2 of which must engage with a culture different from one's personal cultural background. In choosing events, students should be imbued with an attitude of openness to new ideas and a willingness to try something new. The course requires students to share, reflect, and document their participation in a variety of arts events by engaging with classmates and instructors through MyCORE, where they can upload coursework and find postings for events. Coursework can be completed at any time during students' undergraduate years, but they must register for the class during the semester that they intend to complete it, no later than their penultimate semester.

38-230 ENGAGE in Wellness: Looking Inward

Spring: 1 unit

ENGAGE in Wellness: Looking Inward is a 1-unit mini-course that MCS students will enroll in the spring of the sophomore year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this first course, taken in the first mini of the sophomore year, students will select one of three areas on which to focus: intellectual, emotional or physical health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness in this area, develop short-term goals for the next year and a statement of a longer-term goal in this area, identify possible resources and then choose activities that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SOPHOMORES ONLY.

38-301 PROPEL

Spring: 6 units

PROPEL: Preparation, Readiness, and Optimization for Professional Excellence in Life - is a 6-unit seminar course that MCS students will enroll in the spring of their junior year. The course will leverage students' deepening disciplinary perspective in service of the development of competencies, skills and perspectives that are necessary to achieve professional excellence in today's society. The course will use traditional career development activities, such as interviewing, resume writing and networking, as a starting point for students to begin the process of reflecting on, and preparing for, their impending transitions into professional life. From there, the course will seek to expand students' conceptualization of the scientific workplace by exploring the interplay of science, innovation, public policy, entrepreneurship and business in professional settings today. The seminar will also equip students with significant insight into the ways in which global policy, societal and political forces, environmental issues and ethical considerations shape and influence the activity and research of working scientists. The course will offer additional experiences for students to refine their multidisciplinary teamwork and communication skills via small group projects focusing on the aforementioned course themes. Finally, "PROPEL" will include a formal academic advising component to ensure that all students are well positioned to complete the MCS core requirements and departmental requirements in the following year. THIS COURSE IS FOR QBS JUNIORS ONLY.

38-304 Reading and Writing Science

Spring: 6 units

This course is designed to hone the student's ability to read scientific writing and to communicate about scientific topics to audiences with different levels of interest and expertise in science. This course introduces students to frameworks for identifying the linguistic features of scientific argumentation in research papers across a range of scientific disciplines to improve their reading and writing of scientific content. The course also examines how scientific information changes when it is reported in the popular media and the effects these changes have on non-experts' understanding of science. Students will use these changes as a model for writing about scientific research to non-expert audiences. Finally, this course gives students the opportunity to practice science communication by creating oral presentations for their peers. The curriculum in this course is drawn from rhetoric: a discipline focused on the analysis and production of language, arrangement, and argument strategically designed to persuade an audience.

38-330 ENGAGE in Wellness: Looking Outward

Fall: 1 unit

ENGAGE in Wellness: Looking Outward is a 1-unit mini-course that MCS students will enroll in the fall of the junior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this second course, taken in the first mini of the junior year, students will select one of three areas on which to focus: spiritual, environmental and institutional or community health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness, participate in wellness activities on campus or develop short-term goals and longer-term goal in this area, and identify possible resources that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR JUNIORS ONLY.

38-402 MCS Leadership Development Seminar

Fall and Spring: 9 units

This course is designed for 3rd-year and 4th-year Mellon College of Science students committed to further developing their leadership skills and potential for sustained impact in the future. The course will be substantive and engaging, while also ideally thought provoking, edifying, and enjoyable. The course will build on the foundation of six key leadership pillars, identified to hone each students professional and personal development to serve others, and to seek out and nurture opportunities to heighten ones capacity as a person and leader who is: VISIONARY, with clear goals for yourself, your organizations and communities, and others in whose lives you are a part, including the broader society; ETHICAL, with core values and steadfastness in the face of competing objectives, and the resilience to deal with conflicts without moral compromise; ENGAGING, with empathy, attentive interpersonal attributes, outstanding formal and informal communication skills, and the capacity to inspire; TACTICAL, with an ability to operationalize big ideas and bring them to fruition, creating the ideal environment for individual and group success; TECHNICAL, based on your own high-level skill set and the ego strength for inclusion of others with complementary realms of expertise; REFLECTIVE, manifesting in the honest appraisal of personal and organizational success against metrics, and the ability to redirect based on assessment.

38-430 ENGAGE in Wellness: Looking Forward

Fall: 1 unit

ENGAGE in Wellness: Looking Forward is a 1-unit mini-course that MCS students will enroll in the fall of the senior year, designed to give students a holistic understanding of their own personal wellness. The course is structured around the concept of a Wellness Wheel, a model for personal wellness that is used to describe the various areas that students should reflect upon when describing, and ultimately improving, their overall wellness. The MCS Wellness Wheel has nine components: intellectual, physical, emotional, spiritual, environmental, institutional or community, financial, social, and occupational health. During this third course, taken in the first mini of the senior year, students will select one of three areas on which to focus: financial, social and occupational health. They will be asked to engage in a recursive, reflective process to assess their own level of wellness, participate in wellness activities on campus or develop short-term goals and longer-term goal in this area, and identify possible resources that promote this aspect of wellness. Students should expect to devote 9-14 hours to the development and articulation of their plan in order to earn a passing grade. These hours are tied to completion of the requested assessments and not to the activities students' elect to pursue in fulfillment of their wellness plan. THIS COURSE IS FOR SENIORS ONLY.

Minors Offered by the Mellon College of Science

The Mellon College of Science offers several minors to students interested in broadening their scientific training or acquiring a level of expertise in a particular scientific field. The intercollege minors described below are designed to supplement your degree in science; the departmental minors offer you a means of exploring another field and are open to students throughout the university.

Intercollege Minors

Please see the descriptions below.

- Environmental and Sustainability Studies
- Health Care Policy and Management
- Scientific Computing

Departmental Minors in the Mellon College of Science

For descriptions, please see the departmental sections which follow.

- Biological Sciences
- Chemistry
- Computational Finance
- Discrete Mathematics and Logic
- Mathematical Sciences
- Neuroscience
- Physics

Minor in Environmental and Sustainability Studies

Maggie Braun, *MCS Associate Dean for Undergraduate Affairs*
Abigail Owen, *Program Director and Faculty Advisor, Steinbrenner Institute for Environmental Education and Research*

Please see the Intercollege Section (p.) of the catalog for details about this minor.

Minor in Health Care Policy and Management

Sponsored by:

Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:

Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:

| | | |
|--------|--|---|
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 90-436 | Health Systems | 6 |
| 90-472 | Health Policy | 6 |

Elective Courses

Complete a minimum of 24 units from these two sections:

Heinz College Courses

| | | |
|---------------------------|--|----|
| 94-409 | Healthcare Information Systems | 12 |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 90-834 | Health Care Geographical Information Systems | 12 |
| Other courses as approved | | |

Humanities and Social Sciences Courses (9 units each)

| | | |
|---------------------------|--|---|
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 42-444 | Medical Devices | 9 |
| Other courses as approved | | |

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

| | | |
|--|---------------------------|-------|
| Health Management/Administration Focus | | Units |
| 90-832 | Health Law | 6 |
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |

| | | |
|---------------------------|--|-------|
| Health Policy Focus | | Units |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 88-365/90-882 | Behavioral Economics and Public Policy | 9 |
| Other courses as approved | | |

| | | |
|-----------------------------|--|-------|
| Health Analytics & IT Focus | | Units |
| 94-409 | Healthcare Information Systems | 12 |
| 90-834 | Health Care Geographical Information Systems | 12 |
| 42-444 | Medical Devices | 9 |
| Other courses as approved | | |

Minor in Scientific Computing

Dr. Maggie Braun, *Advisor, MCS Dean's Office*
mabraun@andrew.cmu.edu

Sometimes called "computational science," scientific computing is the application of high-performance computers and modern computational technologies to problems in the sciences and engineering. Research in this area is inherently multidisciplinary, requiring strong ties with a scientific discipline.

MCS students can easily build on their scientific training with this applied computational program. The curriculum consists of five areas of concentration, which span the natural sciences, mathematics, programming, and research. The curriculum is structured to allow flexibility in choosing courses that meet students' particular interests or best compliment their major. The minor is also a natural choice for students majoring in any technical area.

Required Courses

Students must meet the requirements of the following categories:

A. Non-Introductory Science Requirement (9-12 units)

Complete 1 course from Biological Sciences, Chemistry, or Physics at the 200 level or higher, excluding those courses listed below as part of the requirements of the minor. Courses with a significant science component from other colleges may be substituted with approval from the minor advisor.

B. Computational Science Requirement (18-24 units)

Complete 2 of the following courses:

| | | |
|--------|--|----|
| 03-511 | Computational Molecular Biology and Genomics | 9 |
| 09-560 | Computational Chemistry | 12 |
| 15-386 | Neural Computation | 9 |
| 33-241 | Introduction to Computational Physics | 9 |

C. Computational Methods Requirement (9 units)

Complete one of the following courses from outside of your home department.

| | | |
|--------|--|----|
| 21-369 | Numerical Methods | 12 |
| 33-658 | Quantum Computation and Quantum Information Theory | 10 |
| 33-232 | Mathematical Methods of Physics | 10 |
| 33-456 | Advanced Computational Physics | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |

D. Applied Scientific Computing Research Project(s) (9 units)

Complete one approved research project in an area of applied scientific computing. In some cases, this research could be replaced with 9 units of an approved project-based course in advanced scientific computing. The administrator of the minor will maintain a list of appropriate courses. Under special circumstances summer research may count toward this requirement, although it cannot be counted toward the units required for graduation.

E. Complete any additional course from category C or D (9 units)

School of Computer Science

Martial Hebert, Dean

Thomas Cortina, Associate Dean for Undergraduate Programs

Veronica Peet, Assistant Dean for Undergraduate Experience

Location: GHC 4115

www.cs.cmu.edu/undergraduate-programs/ (<http://www.cs.cmu.edu/undergraduate-programs/>)

Carnegie Mellon founded one of the first Computer Science departments in the world in 1965. As research and teaching in computing grew at a tremendous pace at Carnegie Mellon, the university formed the School of Computer Science (SCS) at the end of 1988. Carnegie Mellon was one of the first universities to elevate Computer Science into its own academic college at the same level as the Mellon College of Science and the College of Engineering. Today, SCS consists of seven departments and institutes, including the Computer Science Department that started it all, along with the Computational Biology Department, the Human-Computer Interaction Institute, the Language Technologies Institute, the Machine Learning Department, the Robotics Institute and the Software and Societal Systems Department (formerly the Institute for Software Research). Together, these units make SCS a world leader in research and education. Over the last six years, SCS has launched four new primary undergraduate majors in Computational Biology, Artificial Intelligence (the first of its kind in the United States), Human-Computer Interaction, and Robotics. This year, we will launch a new primary major in Robotics. These new majors, along with the highly-ranked Computer Science major, give students in SCS distinct paths in the field of computing with ample opportunities in industry and advanced research.

The School of Computer Science offers the following majors and minors:

- B.S. in Artificial Intelligence
- B.S. in Computational Biology
- B.S. in Computer Science
- B.S. in Human-Computer Interaction
- B.S. in Robotics
- Bachelor's in Computer Science and Art (joint with the College of Fine Arts)
- Additional major in Artificial Intelligence
- Additional major in Computational Biology
- Additional major in Computer Science
- Additional major in Human-Computer Interaction (Interdisciplinary)
- Additional major in Robotics
- Minor in Artificial Intelligence
- Minor in Computational Biology
- Minor in Computer Science
- Minor in Human-Computer Interaction
- Minor in Information Security, Privacy and Policy
- Minor in Language Technologies
- Minor in Machine Learning
- Minor in Neural Computation
- Minor in Robotics
- Minor in Software Engineering

Information for these majors and minors can be found through the navigation menu or through the links below:

- Artificial Intelligence (p. 689) (B.S. degree, additional major, minor)
- Computational Biology (p. 694) (B.S. degree, additional major, minor)
- Computer Science (p. 698) (B.S. degree, additional major, minor)
- Human-Computer Interaction (p. 703) (B.S. degree, additional interdisciplinary major, minor)
- Robotics (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/robotics/>) (B.S. degree, additional major, minor)
- SCS additional majors and minors (p. 714)

Students who apply to, and are directly admitted into, the School of Computer Science can choose between five primary majors: Artificial Intelligence, Computational Biology, Computer Science, Human-Computer Interaction and Robotics. Students with artistic and computing interests may be given the option to pursue a major in Computer Science and Art. Suitably prepared students from other Carnegie Mellon colleges are eligible

to apply for internal transfer to the School of Computer Science and will be considered for transfer if grades in specific requirements are sufficiently high and space is available. Consult the program websites for specific requirements for transfer requests. Computation-oriented programs are also available within the Mellon College of Science, the Dietrich College of Humanities and Social Sciences, the College of Engineering and the College of Fine Arts.

Policies & Procedures

Academic Standards and Actions

Grading Practices

Grades given to record academic performance in SCS are detailed under Grading Practices at Undergraduate Academic Regulations (p. 25).

Dean's List WITH HIGH HONORS

SCS recognizes each semester those undergraduates who have earned outstanding academic records by naming them to the Dean's List with High Honors. The criterion for such recognition is a semester quality point average of at least 3.75 while completing a minimum of 36 factorable units and earning no incomplete grades.

Academic Actions

In the first year, quality point averages below 1.75 in either semester invoke an academic action. For all subsequent semesters an academic action will be taken if the semester quality point average or the cumulative quality point average (excluding the first year) is below 2.00.

Probation: The action of probation will be taken in the following cases based on QPA:

1. One semester of the first year is below 1.75 QPA;
2. The semester QPA of a student in good standing beyond the first year falls below 2.00.

The term of probation is one semester as a full-time student. First year students are no longer on probation at the end of the second semester if the second semester's QPA and the cumulative QPA is 1.75 or above. Students in the third or subsequent semester of study are no longer on probation at the end of one semester if the semester QPA and cumulative QPA (excluding the first year) are 2.00 or above.

Probation Continued: A student who has had one semester on probation and is not yet meeting minimum requirements but whose record indicates that the standards are likely to be met at the end of the next semester of study may be continued on probation, based on advisor recommendation. This action is normally taken only when a student's semester QPA is above 2.0 but their cumulative QPA is not yet above 2.0.

Suspension: A student who does not meet minimum standards based on QPA at the end of one semester of probation can be suspended:

- A first year student will be suspended if the QPA from each semester is below 1.75.
- A student on probation in the third or subsequent semester of study will be suspended if the semester QPA is below 2.00.

The minimum period of suspension is one academic year (two non-summer semesters). Suspension is meant to allow a student to take a pause from their academic studies to address the issues that are causing poor academic performance. At the end of that period a student may return to campus (on probation) by:

1. completing a Return from Leave form from the HUB and submitting this form to their academic advisor, and
2. submitting an additional written statement to their academic advisor and the SCS Associate Dean for Undergraduate Programs, minimum one page, that outlines what the student did while on leave to address the issues that led to the suspension and that would indicate future success on return, and
3. (optional) submitting up to two letters of support from individuals supporting the student's return to the academic advisor and the SCS Associate Dean for Undergraduate Programs.

Upon review by the student's academic advisor and the Associate Dean for Undergraduate Programs, in consultation with the Office of Student Affairs and the Office of International Education as appropriate, the student may be approved to continue their studies.

Students who have been suspended or have withdrawn are required to absent themselves from the campus (including residence halls and Greek houses) within a maximum of two days after the action and to remain off the campus for the duration of the time specified. This action includes debarment from part-time or summer courses at the university for the duration of the period of the action. Although suspended students may not hold student jobs, students on academic suspension may, under certain circumstances, have a non-student job with the university. Students on disciplinary or administrative suspension may not.

Drop: This is a permanent severance. Students who have been suspended and who fail to meet minimum standards in the subsequent semester(s) after they return to school on probation will be dropped from the School of Computer Science. Students who have been dropped and are not admitted to another program at the university are required to absent themselves from the campus (including residence halls and Greek houses) within a maximum of two days after the action.

Appeal: Students may appeal a suspension or drop decision in writing within 10 business days of notification if, under consultation with their academic advisor, they feel that the decision was made in error and they have additional information that would indicate that they can continue in the next semester and exit their probationary status. Instructions on the appeal process are given in the suspension letter that is sent to the student.

Other Actions: In addition to academic actions based on QPA, the Associate Dean for Undergraduate Programs may place students on probation, subsequent suspension or drop, if they do not demonstrate reasonable progress through the core curriculum of their major (e.g., not completing a core class after 3 attempts, not completing the required 100-level core courses by the end of the sophomore year, etc.). Students are encouraged to consult with their academic advisor about any concerns with regard to lack of progress in their chosen SCS major to determine if any course drop or withdrawal will lead to an action.

The relation indicated above between probation, suspension and drop is nominal. In unusual circumstances, SCS College Council may suspend or drop a student without prior probation.

Leave of Absence and Return from Leave of Absence

SCS undergraduate students may elect to take a leave of absence for a variety of reasons, after consultation with their academic advisor. Students who wish to take a leave of absence must do so by the last day of classes before final exams begin and before final grades are posted (in case this is earlier). Students requesting a leave of absence must complete a form from the HUB and have this signed by their academic advisor and SCS Associate Dean for Undergraduate Programs. Students who take a leave of absence up to the last day to drop classes will have all of their classes dropped. Students who take a leave of absence after the last day to drop classes will be assigned a grade of W (withdrawal) for all of their classes.

Students returning from a leave of absence are required to submit a Return from Leave of Absence form to their academic advisor for approval by the student's academic advisor and the SCS Associate Dean for Undergraduate Programs. In addition, for students taking a leave for academic reasons, the student must also supply a letter that explains the reason for the leave, the actions that were performed during the leave to prepare the student for a successful return, and a description of the on-campus resources, if required, that would be used by the student in order to increase the likelihood of success. Students returning from a leave are also encouraged to provide up to two letters of support from people close to the student (e.g. family, friends, clergy, teachers, coaches, others as appropriate). Requests to return are reviewed by the student's academic advisor, the Associate Dean and the Student Affairs liaison to determine eligibility and any resources that need to be put into place to assist the student upon return. Contact the SCS Undergraduate Office (GHC 4115) for more information.

Internal Transfer within SCS

First year students admitted to SCS are considered undeclared during their first year. These students declare their SCS major in the middle of the second semester of their first year of study. SCS students who wish to transfer from one SCS major to another SCS major may do so by applying for transfer by mid-semester break during the semester the transfer is desired (or the end of the summer session for summer transfers). These students should consult with their academic advisor and the program

director of the intended major for more information about specific course requirements and academic plans. Internal SCS transfers do not have any grade requirements. Transfers are approved based on demonstrated interest, ability, and available space in the intended major. Consult the website for the individual SCS major for more information about expected courses to take to demonstrate interest and ability. The transfer request form is available on the SCS website.

Transfer into SCS / Dual-Degree

Undergraduate students admitted to colleges at CMU other than SCS and wishing to transfer to SCS or pursue a dual degree in SCS should consult with the Director or Program Coordinator of the desired SCS major during their first year. See the individual program pages for the names of the current directors and program coordinators, along with their contact information.

- For the Artificial Intelligence primary major, students must complete 15-122, 15-150, 15-281, 10-315, one of 15-210, 15-213 or 15-251, and one of 36-225, 21-325, 36-218 or 15-259, with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Computational Biology primary major, students must complete 21-127 (or equivalent), 15-122, 15-251, 15-351 (or 15-210*), 03-121 and either 02-251 or 02-250 with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree. (*Students who take 15-210 will need to also take 15-150; this course is not required for the B.S. in Computational Biology but can count as an elective.)
- For the Computer Science primary major, students must complete 21-127 (or equivalent), 15-122, 15-150, 15-210, 15-213, 15-251 with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Human-Computer Interaction primary major, students must complete 21-127 (or equivalent), 15-122, 15-150, 05-410, one of 15-210 or 15-213, and one of 05-470 or 05-651, with an expected overall QPA over these six courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.
- For the Robotics primary major, students must complete 21-127 (or equivalent), 15-122, 15-213, 15-251, one of the following robotics courses: 16-211, 16-299, 16-311 (or Robot Building when launched), and one of 36-225, 21-325, 36-218 or 15-259, with an expected overall QPA over these 6 courses of 3.6 or higher and an overall QPA of at least 3.0, in order to be considered for transfer or dual degree.

Students may apply for transfer by the start of the mid-semester break in the semester when the final course(s) of the six required courses will be completed (or the end of the summer session for summer transfer requests). In the case of course(s) in progress, the mid-semester grades will be used in the QPA calculation. The decision to allow transfer or dual degree will be made by committee based on the student's academic performance (in the specified courses and in their courses overall if necessary), additional involvement in SCS and other computing-related activities, and availability of space in the student's class level. Students should consult the SCS Undergraduate Office for complete information concerning minimum requirements, instructions and deadlines.

External Transfer

A student currently enrolled at another university or college who wishes to transfer to SCS should first apply through the Office of Admission. If the Office of Admission believes the applicant meets admission guidelines, the student's record is sent to SCS for evaluation. Admission is based on seat availability, overall academic performance and course rigor from the student's current institution, ability to complete the rigorous SCS program on time, and the application material including recommendations and reflection essay(s). It is important to note that extremely few external transfers are admitted to the SCS program at Carnegie Mellon University due to space limitations.

Graduation Requirements

1. A requirement for graduation is the completion of the program specified for a degree with a cumulative quality point average of 2.00 or higher for all courses taken at CMU. (Students who start their undergraduate

study at CMU may meet this requirement without the first year of study, if necessary.)

- Students must be recommended for a degree by the faculty of SCS.
- A candidate for the bachelor's degree must complete at the University a minimum of four semesters of full-time study, or the equivalent of part-time study, comprising at least 180 units of course work.
- Students will be required to have met all financial obligations to the university before being awarded a degree.

A student who does not meet the QPA requirement above must petition SCS College Council for a waiver of the first requirement.

General Education Requirements

All undergraduate degrees in the School of Computer Science include depth in their particular field of study but also breadth through the general education requirements. General education requirements are part of SCS degrees to give students an opportunity to learn more about the world from scientific and humanistic points of view. These additional skills are useful for graduates since computing is often embedded in domains that are not entirely within the bounds of computing. SCS students will need to use their computing skills to solve problems alongside scientists and engineers, artists, social and cognitive scientists, historians, linguists, economists and business experts, and SCS students will need to communicate effectively and understand the ethical implications of their work. The general education requirements help SCS students gain this broad perspective so they can work well in a wide variety of domains.

Science and Engineering

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT).

Computational Biology majors

For Computational Biology majors, consult the Computational Biology (p. 694) program page for specific science and engineering requirements. The required science and engineering courses for the Computational Biology major also satisfy the General Education requirement for SCS by default.

Artificial Intelligence, Computer Science and Human-Computer Interaction majors

For Artificial Intelligence, Computer Science and Human-Computer Interaction majors, four courses in science and engineering are required, 9 units or more for each course, at least one course must have a laboratory component and at least two courses must be from the same department. Consult with your SCS undergraduate advisor for possible use of any mini course for this requirement which needs to be reviewed by your advisor and the SCS Associate Dean for Undergraduate Programs.

Non-lab courses that are usually taken by AI, CS and HCI majors to satisfy this requirement are given in the list below. (Consult your academic advisor for additional choices available each semester.)

| | | |
|--------|---|----|
| 02-223 | Personalized Medicine: Understanding Your Own Genome (can be paired with a course in Biology 03-xxx for two courses in one department) | 9 |
| 03-121 | Modern Biology | 9 |
| 03-125 | Evolution | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 06-100 | Introduction to Chemical Engineering | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 12-201 | Geology | 9 |
| 18-095 | Getting Started in Electronics: An Experiential Approach | 9 |
| 18-100 | Introduction to Electrical and Computer Engineering | 12 |
| 18-220 | Electronic Devices and Analog Circuits | 12 |
| 18-240 | Structure and Design of Digital Systems | 12 |
| 24-101 | Fundamentals of Mechanical Engineering | 12 |

| | | |
|---------------|---|----|
| 24-231 | Fluid Mechanics | 10 |
| 24-261 | Mechanics I: 2D Design | 10 |
| 24-291-24-381 | Environmental Systems on a Changing Planet - Environmental Systems on a Changing Planet: Science Engineering Addendum (must take both courses together) | 12 |
| 24-351 | Dynamics | 10 |
| 24-358 | Culinary Mechanics | 9 |
| 27-215 | Thermodynamics of Materials | 12 |
| 33-114 | Physics of Musical Sound | 9 |
| 33-120 | Science and Science Fiction | 9 |
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| or 33-151 | Matter and Interactions I | |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| or 33-152 | Matter and Interactions II | |
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-226 | Physics of Energy | 9 |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 42-202 | Physiology | 9 |
| 85-219 | Foundations of Brain and Behavior (can be paired with a course in Biology 03-xxx for two courses in one department) | 9 |

At present, courses meeting the lab requirement include:

| | | |
|--------|---|------|
| 02-261 | Quantitative Cell and Molecular Biology Laboratory (can be paired with a course in Biology 03-xxx for two courses in one department) | 9 |
| 02-262 | Computation and Biology Integrated Research Lab (can be paired with a course in Biology 03-xxx for two courses in one department) | Var. |
| 03-124 | Modern Biology Laboratory | 9 |
| 09-101 | Introduction to Experimental Chemistry (This 3 unit lab together with 09-105 satisfies the lab requirement.) | 3 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 27-100 | Engineering the Materials of the Future | 12 |
| 33-104 | Experimental Physics | 9 |
| 33-228 | Electronics I | 10 |
| 42-203 | Biomedical Engineering Laboratory | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |

The following MCS and CIT courses cannot be used to satisfy the Science and Engineering requirement (see note below this list for additional exceptions and conditions):

| | | |
|--------|--|----|
| 03-511 | Computational Molecular Biology and Genomics | 9 |
| 04-330 | Fundamentals of Software Development and Problem Solving | 12 |
| 06-262 | Mathematical Methods of Chemical Engineering | 12 |
| 09-103 | Atoms, Molecules and Chemical Change | 9 |
| 09-108 | The Illusion and Magic of Food | 6 |
| 09-109 | Kitchen Chemistry Sessions | 3 |
| 09-110 | The Design and Making of Skin and Hair Products | 3 |
| 09-114 | Basics of Food Science | 3 |
| 09-204 | Professional Communication Skills in Chemistry | 3 |
| 09-209 | Kitchen Chemistry Sessions | 3 |
| 09-231 | Mathematical Methods for Chemists | 9 |
| 12-215 | Introduction to Professional Writing in CEE | 9 |
| 12-271 | Computation and Data Science for Civil & Environmental Engineering | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 18-200 | ECE Sophomore Seminar | 1 |
| 18-202 | Mathematical Foundations of Electrical Engineering | 12 |
| 18-213 | Introduction to Computer Systems | 12 |
| 18-330 | Introduction to Computer Security | 12 |
| 18-334 | Network Security | 12 |
| 18-335 | Secure Software Systems | 12 |

| | | |
|--------|--|----|
| 18-411 | Computational Techniques for Data Science and Engineering | 12 |
| 18-441 | Computer Networks | 12 |
| 18-460 | Optimization | 12 |
| 18-461 | Introduction to Machine Learning for Engineers | 12 |
| 18-462 | Principles and Engineering Applications of AI | 12 |
| 18-465 | Advanced Probability & Statistics for Engineers | 12 |
| 18-482 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 18-487 | Introduction to Computer Security | 12 |
| 18-540 | Rapid Prototyping of Computer Systems | 12 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-211 | Ethics and Policy Issues in Computing (or 17-200) | 9 |
| 19-213 | The American Railroad: Decline and Renaissance in the Age of Deregulation | 6 |
| 19-301 | Decision Making Methods for Engineers and Scientists | 9 |
| 19-303 | Cryptocurrencies, Blockchains and Applications | 9 |
| 19-351 | Applied Methods for Technology-Policy Analysis | 9 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-421 | Emerging Energy Policies | 9 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 19-433 | Data Science for Technology, Innovation and Policy | 9 |
| 19-534 | Usable Privacy and Security | 9 |
| 19-608 | Privacy Policy, Law, and Technology | 12 |
| 24-281 | Introduction to Scientific Computing | 2 |
| 24-311 | Numerical Methods | 12 |
| 27-410 | Computational Techniques in Engineering | 12 |
| 33-100 | Basic Experimental Physics | 6 |
| 33-115 | Physics for Future Presidents | 9 |
| 33-124 | Introduction to Astronomy | 9 |
| 33-232 | Mathematical Methods of Physics | 10 |
| 42-201 | Professional Issues in Biomedical Engineering | 3 |
| 49-300 | Integrated Product Conceptualization | 12 |

All Electrical and Computer Engineering graduate courses [18-6xx, 18-7xx, 18-8xx, 18-9xx] **cannot** be used for this requirement. Students interested in Engineering & Public Policy (19-xxx) courses that are not excluded above, including special topics courses, must consult with their SCS undergraduate advisor and the SCS Associate Dean for Undergraduate Programs to determine suitability for this requirement. In general, any MCS or CIT courses that are cross-listed with SCS courses or have significant mathematical or computational content **cannot** be used for this requirement. Students must consult with an SCS undergraduate advisor about any course to be used for the Science and Engineering requirement before registration.

Humanities and Arts

All candidates for a B.S. degree in the School of Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts as prescribed below. Students pursuing a Bachelor's in Computer Science and Art (p.) should consult the general education requirements for that program.

A. Freshman Writing Requirement (9 units)

Complete one of the following writing options for 9 units:

| | | |
|--------|--|---|
| 76-101 | Interpretation and Argument | 9 |
| 76-102 | Advanced First Year Writing: Special Topics (by invitation only) | 9 |

or two of these three writing minis for 9 units total:

| | | |
|--------|---|-----|
| 76-106 | Writing about Literature, Art and Culture | 4.5 |
| 76-107 | Writing about Data | 4.5 |
| 76-108 | Writing about Public Problems | 4.5 |

B. Breadth Requirement (minimum 27 units: 9 units each)

Complete three courses, one each from Category 1, Category 2, and Category 3. Students may use two minis totaling 9 units or more to

satisfy one of the categories, with permission of the Associate Dean for Undergraduate Education, if the minis meet the goals of the desired category. **NOTE: Artificial Intelligence majors replace Category 1 with Category 1A: Cognitive Studies which is a subset of Category 1.**

Category 1 (for all SCS majors except Artificial Intelligence): Cognition, Choice and Behavior - this requirement explores the process of thinking, decision making, and behavior in the context of the individual.

| | | |
|--------|--|---|
| 70-311 | Organizational Behavior | 9 |
| 70-318 | Managing Effective Work Teams | 9 |
| 80-101 | Dangerous Ideas in Science and Society | 9 |
| 80-130 | Introduction to Ethics | 9 |
| 80-150 | Nature of Reason | 9 |
| 80-180 | Nature of Language | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-275 | Metaphysics | 9 |
| 80-330 | Ethical Theory | 9 |
| 85-102 | Introduction to Psychology | 9 |
| 85-104 | Psychopathology | 9 |
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |
| 85-261 | Psychopathology | 9 |
| 85-370 | Perception | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-421 | Language and Thought | 9 |
| 88-120 | Reason, Passion and Cognition | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |

Category 1A (for Artificial Intelligence majors): Cognitive Studies - this requirement explores how the brain and the mind work.

| | | |
|--------|--|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-370 | Perception | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-421 | Language and Thought | 9 |

Category 2 (all SCS majors): Economic, Political and Social Institutions - this requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.

| | | |
|--------|---|----|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 36-303 | Sampling, Survey and Society | 9 |
| 66-221 | Topics of Law: Introduction to Intellectual Property Law | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 79-101 | Making History: How to Think About the Past (and Present) | 9 |
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-244 | Women in American History | 9 |
| 79-253 | Imperialism and Decolonization in South Asia | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-383 | The History of Capitalism | 9 |
| 79-391 | Nations and Nationalisms in South Asia | 9 |

| | | | | | |
|---|--|---|---|--|---|
| 79-392 | Europe and the Islamic World | 9 | 79-281 | Introduction to Religion | 9 |
| 80-135 | Introduction to Political Philosophy | 9 | 79-282 | Europe and the World Since 1800 | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 | 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 80-244 | Environmental Ethics | 9 | 79-316 | Photography, the First 100 Years, 1839-1939 | 9 |
| 80-245 | Medical Ethics | 9 | 79-345 | Roots of Rock & Roll | 9 |
| 80-324 | Philosophy of Economics | 9 | 79-350 | Early Christianity | 9 |
| 80-335 | Social and Political Philosophy | 9 | 76-386 | Language & Culture | 9 |
| 80-334 | Social and Political Philosophy | 9 | 79-104 | Global Histories | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 | 79-293 | Inward Odyssey | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 | 79-378 | Gender in South Asia | 9 |
| 84-110 | Foundations of Political Economy | 9 | 79-393 | Institutions of the Roman Church | 9 |
| 84-275 | Comparative Politics | 9 | 79-395 | The Arts in Pittsburgh | 9 |
| 84-310 | International Political Economy | 9 | 79-396 | Music, Art, and Society in 19th and 20th Century Europe and the U.S. | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 | 79-465 | The Arts in Qatar | 9 |
| 84-324 | The Future of Democracy | 9 | 80-100 | Introduction to Philosophy | 9 |
| 84-352 | Representation and Voting Rights | 9 | 80-250 | Ancient Philosophy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 | 80-251 | Modern Philosophy | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 | 80-253 | Continental Philosophy | 9 |
| 84-380 | US Grand Strategy | 9 | 80-254 | Analytic Philosophy | 9 |
| 84-386 | The Privatization of Force | 9 | 80-255 | Pragmatism: Making Ideas Work | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 | 80-261 | Experience, Reason, and Truth | 9 |
| 84-389 | Terrorism and Insurgency | 9 | 80-276 | Philosophy of Religion | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 | 82-267 | Beyond the Mafia and Michelangelo | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 | 82-273 | Introduction to Japanese Language and Culture | 9 |
| 84-402 | Judicial Politics and Behavior | 9 | 82-279 | Anime - Visual Interplay between Japan and the World | 9 |
| 84-405 | The Future of Warfare | 9 | 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 | 82-286 | Cultural Complexities | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 | 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| Category 3 (all SCS majors): Cultural Analysis - this requirement seeks to recognize cultures that have shaped and continue to shape the human experience; courses in this category are usually either broad in place, time, or cultural diversity. | | | | | |
| 48-240 | History of World Architecture, I | 9 | 82-294 | 19th Century Russian Masterpieces | 9 |
| 48-241 | History of Modern Architecture | 9 | 82-303 | French & Francophone Cultures | 9 |
| 57-173 | Survey of Western Music History | 9 | 82-304 | French & Francophone Sociolinguistics | 9 |
| 60-105 | Cultural History of the Visual Arts | 9 | 82-313 | Topics in Modern Arabic Language, Literature and Culture | 9 |
| 60-106 | Cultural History of the Visual Arts - the Modern Period | 9 | 82-314 | Literature of the Arabic-speaking World | 9 |
| 62-371 | Photography, The First 100 Years, 1839-1939 | 9 | 82-327 | The Emergence of the German Speaking World | 9 |
| 70-342 | Managing Across Cultures | 9 | 82-333 | Chinese Language and Culture | 9 |
| 70-348 | Cross-Cultural Business Communications | 9 | 82-342 | Spain: Language and Culture | 9 |
| 76-221 | Books You Should Have Read By Now | 9 | 82-343 | Latin America Language and Culture | 9 |
| 76-232 | Introduction to Black Literature | 9 | 82-344 | U.S. Latinos: Language and Culture | 9 |
| 76-239 | Introduction to Film Studies | 9 | 82-345 | Introduction to Hispanic Literary and Cultural Studies | 9 |
| 76-241 | Introduction to Gender Studies | 9 | 82-436 | Introduction to Classical Chinese | 9 |
| 76-243 | Introduction to Television | 9 | C. Humanities and Arts Electives (minimum 27 units) | | |
| 79-145 | Genocide and Weapons of Mass Destruction | 9 | Complete 3 non-technical courses of at least 9 units each from any of the departments in the Dietrich College of Humanities & Social Sciences or the College of Fine Arts. Some of the courses taught in these units are considered technical courses and may not be used to satisfy this requirement (see Deletions below). Additionally, a select set of courses from Business Administration and from Environmental and Public Policy can also count for this requirement (see Additions below). Students may combine humanities/arts courses with lower units together to form a single course of 9 units or more. Students are encouraged, but not required, to take courses from different departments to gain additional breadth and to create new opportunities for engagement with the university community. | | |
| 79-201 | Introduction to Anthropology | 9 | Deletions | | |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 | Some courses from the Dietrich College or the College of Fine Arts may <u>not</u> count toward the unconstrained electives in Humanities and Arts in SCS due to the technical (computing and/or mathematical) nature of the courses. Courses from the following departments do not count toward the unconstrained Humanities and Arts electives: | | |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 | • Statistics and Data Science (36), except 36-303 Sampling, Survey and Society | | |
| 79-226 | African History: Earliest Times to 1780 | 9 | • Information Systems (67) | | |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 | • Economics (73), except 73-102 Principles of Microeconomics and 73-103 Principles of Macroeconomics | | |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 | Additionally, the following courses do NOT count toward the unconstrained Humanities and Arts electives: | | |
| 79-234 | Technology and Society | 9 | | | |
| 79-240 | Development of American Culture | 9 | | | |
| 79-241 | African American History: Africa to the Civil War | 9 | | | |
| 79-242 | African American History: Reconstruction to the Present | 9 | | | |
| 79-245 | Capitalism and Individualism in American Culture | 9 | | | |
| 79-248 | U.S. Constitution & the Presidency | 9 | | | |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 | | | |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 | | | |
| 79-265 | Russian History: Game of Thrones | 9 | | | |

| | | |
|--------|---|------|
| 51-257 | Introduction to Computing for Creative Practices | 10 |
| 51-327 | Design Center: Introduction to Web Design | 9 |
| 51-328 | Design Center: Design for Digital Systems | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-487 | Web Design | 12 |
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-212 | Arguments and Logical Analysis | 9 |
| 80-305 | Game Theory | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |
| 80-315 | Modal Logic | 9 |
| 80-316 | Logic and AI | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |
| 80-405 | Game Theory | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |
| 80-419 | Interactive Theorem Proving | 9 |
| 80-514 | Categorical Logic | 9 |
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | Var. |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-426 | Learning in Humans and Machines | 9 |
| 88-251 | Empirical Research Methods | 9 |
| 88-372 | Social and Emotional Brain | 9 |

Additions

The following courses outside of Dietrich College and the College of Fine Arts may count toward the unconstrained Humanities and Arts electives:

| | | |
|--------|--|----|
| 11-423 | ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang. | 12 |
| 16-161 | ROB Freshman Seminar: Artificial Intelligence and Humanity | 9 |
| 16-397 | Art, Conflict and Technology | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-562 | Law of Computer Technology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-351 | Applied Methods for Technology-Policy Analysis | 9 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-411 | Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 21-150 | Mathematics and the Arts | 9 |
| 32-201 | Leadership & Management | 9 |
| 32-402 | Leadership and Ethics | 9 |
| 70-100 | Global Business | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-318 | Managing Effective Work Teams | 9 |
| 70-321 | Negotiation and Conflict Resolution | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 70-340 | Business Communications | 9 |
| 70-341 | Team Dynamics and Leadership | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 70-345 | Business Presentations | 9 |
| 70-348 | Cross-Cultural Business Communications | 9 |
| 70-350 | Acting for Business | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-381 | Marketing I | 9 |
| 70-430 | International Management | 9 |

Honors Research Thesis

Students considering going on to graduate school in Computer Science or related disciplines should take a wide variety of Computer Science and

Mathematics courses, as well as consider getting involved in independent research as early as possible. This would be no later than the junior year and can begin even earlier. Students interested in graduate school in computer science or its related areas are strongly encouraged to participate in the SCS Honors Undergraduate Research Thesis program. Additionally, graduate CS courses can be taken with permission of the instructor and in consultation with an academic advisor.

The goal of the SCS Honors Undergraduate Research Thesis Program is to introduce students to the breadth of tasks involved in independent research, including library work, problem formulation, experimentation, analysis, technical writing and public speaking. In particular, students write a short paper summarizing prior results and current progress in their desired area of research, present a public poster session in December of their senior year describing their current progress, present their final results with a poster and an oral presentation in the year-end university-wide Undergraduate Research Symposium (Meeting of the Minds) and submit a written thesis at the end of their senior year. Students work closely with faculty research advisors to plan and carry out their research. The 07-599 SCS Honors Undergraduate Research Thesis typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Students should prepare their research prospectus (i.e. proposal of work) during the spring semester of their junior year, and students in this program are advised to plan their schedules carefully to ensure there is ample time to perform the required research for the thesis during the senior year.

Students interested in research are urged to consult with their undergraduate advisor and the SCS Associate Dean for Undergraduate Programs no later than the end of their sophomore year in order to plan their workload effectively. Although there is no specific QPA requirement to participate, students are expected to have at least a 3.5 QPA in the core SCS topics relevant to their proposed research to be successful in their work. For those students with no background in research, they may consider using 07-300 Research and Innovation in Computer Science (9 units) as an introduction to the research process in their junior year since this course will introduce students to various research projects going on in the School of Computer Science and important skills that are needed to be an effective researcher. This course leads to a subsequent research practicum, 07-400 Research Practicum in Computer Science (12 units), that allows students to complete a small-scale research study or experiment and present a research poster. Students who use this practicum to start their senior thesis can use the units toward the required 36 units. Students should consult with their academic advisor concerning how the units earned toward the senior thesis can be used toward elective requirements for their major.

Interested juniors should submit a project prospectus of 3-4 pages by the end of their junior year, although submissions over the summer prior to the senior year will also be considered for review. A prospectus must include:

- The name of the research advisor (an SCS faculty member)
- A short abstract (two paragraphs, max)
- A description of the problem to be worked on and its significance
- A tactical description of the proposed research plan, including:
 - a description of the background reading to be carried out,
 - a description of the research contribution,
 - a description of the expected results of the research, and
 - a reasonably detailed timeline for the thesis work
- A bibliography of related work (all references belong here)
- The signature of the research advisor, signifying endorsement of the project and willingness to supervise and evaluate it (or an email confirmation from the research advisor)

Students who need help finding potential advisors should get in touch with their academic advisor or the Associate Dean for Undergraduate Programs. Applications to the program are due by the start of the senior year, although submission of applications in the junior year is encouraged.

Students completing an outstanding senior thesis based on the judgement of the SCS Undergraduate Review Committee will earn SCS College Honors and can compete for various SCS research awards given out during commencement.

Faculty

UMUT ACAR, Associate Professor, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2012–

ANIL ADA, Associate Teaching Professor, Carnegie Mellon University – Ph.D., McGill University; Carnegie Mellon, 2014–

HENNY ADMONI, Associate Professor, Robotics Institute – Ph.D., Yale University; Carnegie Mellon, 2017–

- YUVRAJ AGARWAL, Associate Professor, Institute for Software Research – Ph.D., University of California, San Diego; Carnegie Mellon, 2013–
- JONATHAN ALDRICH, Professor, Institute for Software Research – Ph.D., University of Washington; Carnegie Mellon, 2003–
- VINCENT ALEVEN, Professor, Human-Computer Interaction Institute – Ph.D., University Of Pittsburgh; Carnegie Mellon, 2000–
- DANIEL ANDERSON, Assistant Teaching Professor, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–
- DAVID ANDERSEN, Professor, Computer Science Department – Ph.D., Massachusetts Institute Of Technology; Carnegie Mellon, 2005–
- JOHN ANDERSON, R.K. Mellon University Professor – Ph.D., Stanford University; Carnegie Mellon, 1978–
- DIMITRIOS APOSTOLOPOULOS, Principal Systems Scientist, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1989–
- SWARNALATHA ASHOK, Associate Teaching Professor, Institute for Software Research – MSc(Tech), Birla Institute of Technology and Science; Carnegie Mellon, 2022–
- CHRISTOPHER ATKESON, Professor, Robotics Institute – Ph.D., Massachusetts Institute Of Technology; Carnegie Mellon, 2000–
- JAMES BAGNELL, Associate Professor, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004–
- ANDREA BAJCSY, Assistant Professor, Robotics Institute – Ph.D., University of California, Berkeley; Carnegie Mellon, 2023–
- MARIA FLORINA BALCAN, Professor, Machine Learning Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–
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- RITA SINGH, Associate Research Professor, Language Technologies Institute – Ph.D., National Geophysical Research Institute; Carnegie Mellon, 2010–
- MICHAEL SKIRPAN, Assistant Teaching Professor, Software and Societal Systems Department – Ph.D., University of Colorado Boulder; Carnegie Mellon, 2023–
- DANIEL SLEATOR, Professor, Computer Science Department – Ph.D., Stanford University; Carnegie Mellon, 1985–
- STEPHEN SMITH, Research Professor, Robotics Institute – Ph.D., University of Pittsburgh; Carnegie Mellon, 1982–
- VIRGINIA SMITH, Assistant Professor, Machine Learning Department – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–
- PETER SPIRITES, Professor, Philosophy – Ph.D., University of Pittsburgh; Carnegie Mellon, 1983–
- JOHN STAMPER, Associate Professor, Human-Computer Interaction Institute – Ph.D., University of North Carolina At Charlotte; Carnegie Mellon, 2009–
- PETER STEENKISTE, Professor, Computer Science Department – Ph.D., Stanford University; Carnegie Mellon, 1987–
- MARK STEHLIK, Teaching Professor, Computer Science Department – B.S., Pace University; Carnegie Mellon, 1981–
- AARON STEINFELD, Research Professor, Robotics Institute – Ph.D., University of Michigan; Carnegie Mellon, 2001–
- GEORGE STETTEN, Adjunct Research Professor, Robotics Institute – Ph.D., University of North Carolina; Carnegie Mellon, 1999–
- EMMA STRUBELL, Assistant Professor, Language Technologies Institute – Ph.D., University of Massachusetts, Amherst; Carnegie Mellon, 2020–
- JOSHUA SUNSHINE, Systems Scientist, Institute for Software Research – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014–
- KLAUS SUTNER, Teaching Professor, Computer Science – Ph.D., University of Munich; Carnegie Mellon, 1995–
- KATIA SYCARA, Research Professor, Robotics Institute – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 1987–
- WENNIE TABIB, Systems Scientist, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–
- AMEET TALWALKAR, Associate Professor, Machine Learning Department – Ph.D., New York University, Courant Institute; Carnegie Mellon, 2017–
- MICHAEL TAYLOR, Assistant Teaching Professor, Computer Science Department – MSR, Carnegie Mellon University; Carnegie Mellon, 2020–
- ZEYNEP TEMEL, Assistant Professor, Robotics Institute – Ph.D., Sabanci University (Istanbul, Turkey); Carnegie Mellon, 2019–
- CHRIS TIMPERLEY, Senior Systems Scientist, Software and Societal Systems – Ph.D., University of York, UK; Carnegie Mellon, 2018–
- DAVID TOURETZKY, Research Professor, Computer Science Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1984–
- MATTHEW TRAVERS, Senior Systems Scientist, Robotics Institute – Ph.D., Northwestern University; Carnegie Mellon, 2013–
- BOGDAN VASILESCU, Associate Professor, Institute for Software Research – Ph.D., Eindhoven University of Technology; Carnegie Mellon, 2016–
- MARIA MANUELA VELOSO, Professor Emeritus, Machine Learning Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1992–
- RASHMI VINAYAK, Associate Professor, Computer Science Department – Ph.D., University of California at Berkeley; Carnegie Mellon, 2017–
- LAURA VINCHESI, Assistant Teaching Professor, Human Computer Interaction Institute – MFA, Cranbrook Art Academy; Carnegie Mellon, 2023–
- PAT VIRTUE, Assistant Teaching Professor, Computer Science Department and Machine Learning Department – Ph.D., University of California at Berkeley; Carnegie Mellon, 2018–
- ALEXANDER WAIBEL, Professor, Language Technologies Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1988–
- WEINA WANG, Assistant Professor, Computer Science Department – Ph.D., Arizona State University; Carnegie Mellon, 2018–
- WENSHEN WANG, Systems Scientist, Robotics Institute – Ph.D., Shanghai Jiao Tong University; Carnegie Mellon, 2023–
- LEILA WEHBE, Assistant Professor, Machine Learning Department – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–
- DAVID WETTERGREEN, Research Professor, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2000–
- WILLIAM RED WHITTAKER, University Research Professor, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1973–
- BRYAN WILDER, Assistant Professor, Machine Learning Department – Ph.D., Harvard University; Carnegie Mellon, 2022–
- DAVID WOODRUFF, Professor, Computer Science Department – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–
- WEI WU, Senior Systems Scientist, Computational Biology Department – Ph.D., Rutgers University; Carnegie Mellon, 2011–
- SHERRY TONGSHUAN WU, Assistant Professor, Human Computer Interaction Institute – Ph.D., Washington University, Saint Louis; Carnegie Mellon, 2022–
- STEVEN WU, Assistant Professor, Software and Societal Systems Department – Ph.D., University of Pennsylvania; Carnegie Mellon, 2020–
- FRANCESKA XHAKAJ, Assistant Teaching Professor, Computer Science Department/ Human Computer Interaction Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2021–
- POE ERIC XING, Professor, Machine Learning Department – Ph.D., University Of California At Berkeley; Carnegie Mellon, 2004–
- CHENYAN XIONG, Associate Professor, Language Technologies Interaction Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–
- MIN XU, Associate Professor, Computational Biology Department – Ph.D., University of Southern California; Carnegie Mellon, 2016–
- YIMING YANG, Professor, Language Technologies Institute – Ph.D., Kyoto University; Carnegie Mellon, 1996–
- NESRA YANNIER, Senior Systems Scientist, Human Computer Interaction Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–
- LINING YAO, Associate Professor, Human Computer Interaction Institute – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2017–
- YUN WILLIAM YU, Assistant Professor, Computational Biology Department – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–
- WENZHEN YUAN, Assistant Professor, Robotics Institute – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2019–
- MARTIN ZHANG, Assistant Professor, Computational Biology Department – Ph.D., Stanford University; Carnegie Mellon, 2023–
- JJ ZHANG, System Scientist, Robotics Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–
- HAIYI ZHU, Associate Professor, Human Computer Interaction Institute – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2019–
- JUN-YAN ZHU, Assistant Professor, Robotics Institute – Ph.D., University of California, Berkeley; Carnegie Mellon, 2020–
- JOHN ZIMMERMAN, Professor, Human-Computer Interaction Institute – M.Des., Carnegie Mellon University; Carnegie Mellon, 2002–

Artificial Intelligence Program

Reid Simmons, Director of the BSAI program (NSH 3213)

Kaleigh Mitchell, Program Administrator (GHC 4113)
www.cs.cmu.edu/bs-in-artificial-intelligence (<http://www.cs.cmu.edu/bs-in-artificial-intelligence/>)

Overview

Carnegie Mellon University has led the world in artificial intelligence education and innovation since the field was created. It's only natural, then, that the School of Computer Science would offer the nation's first bachelor's degree in Artificial Intelligence, which started in Fall 2018.

The BSAI program gives students the in-depth knowledge needed to transform large amounts of data into actionable decisions. The program and its curriculum focus on how complex inputs — such as vision, language and huge databases — can be used to make decisions or enhance human capabilities. The curriculum includes coursework in computer science, math, statistics, computational modeling, machine learning and symbolic computation. Because Carnegie Mellon is devoted to AI for social good, students will also take courses in ethics and social responsibility, with the option to participate in independent study projects that change the world for the better — in areas like healthcare, transportation and education.

Just as AI unites disciplines from machine learning to natural language processing, instruction in the BSAI program includes faculty members from the school's Computer Science Department, Human-Computer Interaction Institute, Institute for Software Research, Language Technologies Institute, Machine Learning Department and Robotics Institute.

Students in the BSAI program within the School of Computer Science are expected to acquire the following skills upon graduation:

- Understand how to distill a real-world challenge as an artificial intelligence problem, involving explicit representation and learning of symbolic and numeric models; reasoning about such models; and using such models for decision making, action selection, and interaction with humans.
- Design, analyze, implement, and use state-of-the-art AI and machine learning techniques for dealing with real-world data, including data involving vision, language, perception, and uncertainty.
- Master the core concepts of computer science, with emphasis on data structures, programming, computing systems, and algorithm design, performance, and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, what is computable).
- Master the fundamentals of discrete mathematics, logic, theorem proving and explanation, probability and statistics, and optimization.
- Describe, specify, and develop large-scale, open-ended artificial intelligence systems subject constraints such as performance, available data, and need for transparency. Communicate technical material effectively to technical and non-technical audiences.
- Work productively both individually and in teams.
- Recognize the social impact of artificial intelligence and the underlying responsibility to consider the ethical, privacy, moral, and legal implications of artificial intelligence technologies.

Students who graduate with a bachelors degree in AI, will have the computer science savvy and skills our students are known for, with the added expertise in machine learning and automated reasoning that you'll need to build the AI of tomorrow.

How to Apply

If you're applying to CMU, you need to be accepted into the School of Computer Science. Once you're at CMU and enrolled in SCS, you can declare a BSAI major in the spring of your first year or transfer into the program in your sophomore or junior year. If you are already at CMU but not in SCS, you can apply to transfer into the program after your sophomore year. Consult with the director or the program administrator of the BSAI program for information.

Curriculum

BSAI majors will take core courses in math and statistics, computer science, artificial intelligence and ethics, along with general education courses in science and engineering, and humanities and arts.

Math and Statistics

| All of the following: | | Units |
|-----------------------|--|-------|
| 15-151 | Mathematical Foundations for Computer Science (if not offered, substitute 21-127) | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-259 | Calculus in Three Dimensions or 21-266, or 21-268, or 21-269 | 10 |
| 36-218 | Probability Theory for Computer Scientists or: (15-259 or 21-325 or 36-225) and 36-226 | 9 |
| 36-401 | Modern Regression | 9 |

Computer Science

| All of the following: | | Units |
|-----------------------|---|-------|
| 15-122 | Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122) | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Artificial Intelligence

| All of the following AI core courses: | | Units |
|---|---|-------|
| 07-180 | Concepts in Artificial Intelligence | 5 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| plus one of the following AI core courses: | | |
| 16-385 | Computer Vision | 12 |
| 11-411 | Natural Language Processing | 12 |
| One Decision Making and Robotics course (min. 9 units): | | Units |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| others as designated by the AI Undergraduate Program | | |

One Machine Learning course from the following (min.9 units):

| | | |
|--------|---|----|
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-485 | Introduction to Deep Learning | 9 |

| | | |
|--|------------------------------------|---|
| 36-402 | Advanced Methods for Data Analysis | 9 |
| others as designated by the AI Undergraduate Program | | |

One Perception and Language course from the following (min. 9 units):

| | | |
|--|---------------------------|----|
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Processing | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-421 | Vision Sensors | 12 |
| others as designated by the AI Undergraduate Program | | |

One Human-AI Interaction course from the following (min. 12 units):

| | | |
|--|--|----|
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Human Robot Interaction | 12 |
| others as designated by the AI Undergraduate Program | | |

School of Computer Science Electives

Two general computer science electives:

Units
18

These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)

Ethics Course

One of the following courses:

Units

| | | |
|--------|---------------------------------------|----|
| 80-249 | AI, Society, and Humanity | 9 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 16-735 | Ethics and Robotics | 12 |

SCIENCE AND ENGINEERING

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 680).

Humanities and Arts

All candidates for the bachelor's degree in Artificial Intelligence must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 680). **SPECIAL NOTE FOR AI STUDENTS: AI majors must satisfy Category 1 of the General Education requirements by taking one of the following Cognitive Studies (Category 1A) courses:**

- 85-211 Cognitive Psychology
- 85-213 Human Information Processing and Artificial Intelligence
- 85-370 Perception
- 85-408 Visual Cognition
- 85-421 Language and Thought

SCS First year seminar

The following course is designed to acquaint incoming students with computer science at CMU:

| | | |
|--------|-------------------------------|---|
| 07-128 | First Year Immigration Course | 3 |
|--------|-------------------------------|---|

Computing @ Carnegie Mellon

The following course is required of all students to familiarize them with the campus computing environment:

| | | |
|--------|-----------------------------|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
|--------|-----------------------------|---|

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

| Area | Courses | Units |
|---|---------|------------|
| Mathematics | 7 | 71 |
| Computer Science | 5 | 60 |
| Artificial Intelligence | 8 | 80 |
| SCS Electives | 2 | 18 |
| Ethics | 1 | 9 |
| Science/Engineering | 4 | 36 |
| Humanities/Arts (includes Cognitive Studies) | 7 | 63 |
| SCS First Year Seminar | 1 | 3 |
| Computing @ Carnegie Mellon | 1 | 3 |
| Free Electives | varies | 17 |
| | | 360 |

Undergraduate Research Thesis

AI majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward SCS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using 07-300 Research and Innovation in Computer Science in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent practicum that allows students to complete a small-scale research study or experiment and present a research poster. Students who use the practicum to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 683) section for learning objectives, application requirements and expected outcomes.

BSAI Roadmap: Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and introductory calculus. Students with no credit for introductory programming will take 15-112 in their first semester and shift some CS courses to later semesters after consulting with their academic advisor; students with no credit for calculus will take 21-120 in their first semester and shift 21-122 and 21-259 to subsequent semesters. These students should still be able to complete their degree in four years given the light load of their senior year. Students with credit for 21-120 and 21-122 may start with a more advanced math class (e.g. 21-241) in their first year. It is recommended that students keep their academic load lighter for their senior fall semester to account for offsite job interviews or for their senior spring semester to account for visits to graduate schools.

FRESHMAN YEAR:

| Fall | | Units |
|--------|---|-------|
| 07-128 | First Year Immigration Course | 3 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| 21-122 | Integration and Approximation | 10 |
| 76-101 | Interpretation and Argument | 9 |

| | | |
|--------|--------------------------------------|-----------|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| | | 49 |
| Spring | | Units |
| 07-180 | Concepts in Artificial Intelligence | 5 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-259 | Calculus in Three Dimensions | 10 |
| | | 50 |

SOPHOMORE YEAR:

| | | |
|--------|---|-----------|
| Fall | | Units |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Ethics Elective | 9 |
| | | 51 |

| | | |
|--------|---|-----------|
| Spring | | Units |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 85-xxx | Cognitive Studies Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| | | 51 |

JUNIOR YEAR:

| | | |
|-----------|-------------------------------|-----------|
| Fall | | Units |
| 11-411 | Natural Language Processing | 12 |
| or 16-385 | Computer Vision | |
| 36-401 | Modern Regression | 9 |
| xx-xxx | AI Elective: Machine Learning | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |

| | | |
|--------|---|-----------|
| Spring | | Units |
| xx-xxx | AI Elective: Human-AI Interaction | 12 |
| xx-xxx | AI Elective: Decision Making and Robotics | 9 |
| xx-xxx | Science and Engineering elective | 9 |
| xx-xxx | Humanities and Arts elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 48 |

SENIOR YEAR:

| | | |
|--------|--------------------------------------|-----------|
| Fall | | Units |
| xx-xxx | AI Elective: Perception and Language | 9 |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Science and Engineering Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| | | 36 |

| | | |
|--------|------------------------------|-----------|
| Spring | | Units |
| xx-xxx | SCS Elective | 9 |
| xx-xxx | Humanities and Arts Elective | 9 |
| xx-xxx | Free Elective | 9 |
| | | 27 |

Minimum number of units required for the degree:360

The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). AI cluster electives (decision making and robotics, machine learning, perception and language, and human-AI interaction) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective

options depending on course availability, their academic interests and their career goals.

Additional Major in Artificial Intelligence

Students interested in pursuing an additional major in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu). Students must have all prerequisites completed, 21-112 or 21-120, 15-122, 15-150, one of 15-210, 15-213, or 15-251, as well as 15-281 or 10-315. Students must earn a "B" average in all prerequisite coursework in order to be admitted to the additional major. The additional major requires 6 mathematics courses, 5 computer science courses, 2 artificial intelligence courses, 4 courses from AI cluster areas, 1 course in ethics, and 1 course in human cognition.

Prerequisites

| | | |
|------------|--|-------|
| (1 course) | | Units |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

The following courses are required for the Addition Major in Artificial Intelligence:

Math and Statistics Core

| | | |
|-------------------------------------|--|-------|
| (6 courses) | | Units |
| 21-112 | Calculus II | 10 |
| or 21-120 | Differential and Integral Calculus | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| or 15-151 | Mathematical Foundations for Computer Science | |
| 21-122 | Integration and Approximation | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| Probability and Statistics (one of) | | |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference | 18 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 15-259-15-260 | Probability and Computing - Statistics and Computing | 15 |
| 21-325-36-226 | Probability - Introduction to Statistical Inference | 18 |
| Modern Regression Course | | |
| 36-401 | Modern Regression | 9 |

Computer Science Core

| | | |
|-------------|--|-------|
| (5 courses) | | Units |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Artificial Intelligence Core

| | | |
|-------------|---|-------|
| (2 courses) | | Units |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |

AI Cluster Electives

| | | |
|---|--|-------|
| (4 courses, one from each cluster area) | | Units |
| Cognition and Action Cluster (1 course) | | |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| Machine Learning Cluster (1 course) | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |

| | | |
|--|---|----|
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| Perception and Language Cluster (1 course) | | |
| 11-411 | Natural Language Processing | 12 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Processing | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-385 | Computer Vision | 12 |
| Human-AI Interaction Cluster (1 course) | | |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Human Robot Interaction | 12 |

Ethics and Human Cognition

(2 courses, one from each cluster area)

Ethics (1 course)

| | | |
|--------|---------------------------------------|----|
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 80-249 | AI, Society, and Humanity | 9 |

Human Cognition (1 course)

| | | |
|--------|--|---|
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-370 | Perception | 9 |
| 85-345 | Meaning in Mind and Brain | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

*Note that Concepts in Artificial Intelligence (07-180) is not required for additional majors, although students interested in the additional major in AI are encouraged to take 07-180 prior to taking 15-281 or 10-315.

Double Counting Restrictions

Students pursuing an additional major in AI can double count at most **five courses** total, from the Computer Science Core, the Artificial Intelligence Core, and the AI Cluster Electives, towards all other majors and minors they're pursuing. The Mathematics, Ethics, and Human Cognition courses may double count without restriction, except for 36-402 (Advanced Methods for Data Analysis), which is part of the Machine Learning Cluster. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.

Artificial Intelligence Minor

Students interested in pursuing a minor in Artificial Intelligence should first consult with the Program Administrator (bsai@cs.cmu.edu) after completion of the prerequisites and 15-281 or 10-301/10-315. Students must earn a "C" average in all prerequisite coursework (including 15-281 or 10-301/10-315) in order to be admitted to the minor. The minor includes 3 required core courses, and 5 courses from AI cluster areas.

Prerequisites

| | | |
|-------------|--------------------------------------|-------|
| (4 courses) | | Units |
| 15-122 | Principles of Imperative Computation | 12 |
| 21-112 | Calculus II | 10 |
| or 21-120 | Differential and Integral Calculus | |
| or 21-259 | Calculus in Three Dimensions | |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |

| | | |
|-----------|---|----|
| or 15-151 | Mathematical Foundations for Computer Science | |
| 21-240 | Matrix Algebra with Applications | 10 |
| or 21-241 | Matrices and Linear Transformations | |

The following courses are required for the Minor in Artificial Intelligence:

Required Core

| | | |
|--|---|-------|
| (3 courses) | | Units |
| *Two mini courses can be combined to form one 9 unit course. | | |
| 36-225 | Introduction to Probability Theory | 9 |
| or 21-325 | Probability | |
| or 36-218 | Probability Theory for Computer Scientists | |
| or 15-259 | Probability and Computing | |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |

Technical Electives

| | | |
|---|---|-------|
| (2 courses from any of the three areas) | | Units |
| Cognition and Action Cluster | | |
| 15-386 | Neural Computation | 9 |
| 15-482 | Autonomous Agents | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-350 | Planning Techniques for Robotics | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |
| Machine Learning Cluster | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418 | Machine Learning for Structured Data | 12 |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 15-388 | Practical Data Science | 9 |
| or 67-364 | Practical Data Science | |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| Perception and Language Cluster | | |
| 11-411 | Natural Language Processing | 12 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Processing | 12 |
| 15-387 | Computational Perception | 9 |
| 15-463 | Computational Photography | 12 |
| 16-385 | Computer Vision | 12 |
| 85-370 | Perception | 9 |
| 85-345 | Meaning in Mind and Brain | 9 |
| 85-408 | Visual Cognition | 9 |

Societal Aspects of AI

| | | |
|--|--|-------|
| (1 course from one of the two cluster areas) | | Units |
| *Two mini courses can be combined to form one 9 unit course. | | |
| Human-AI Interaction Cluster | | |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-318 | Human AI Interaction | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 16-467 | Human Robot Interaction | 12 |
| AI and Humanity Cluster | | |

| | | |
|--------|--|----|
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 79-302 | Killer Robots:The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 90-442 | Critical AI Studies for Public Policy | 6 |
| 94-441 | Ethics and Politics of Data | 6 |

Double Counting Restriction

Students pursuing a minor in AI can double count, at most, **two courses** total from the AI course requirements towards all other majors and minors they're pursuing. Students with majors that overlap substantially with AI should consult with the Program Administrator (bsai@andrew.cmu.edu) to review their audit for any potential issues.

Computational Biology Program

Russell Schwartz, PhD, Department Head
Location: GHC 7725

Phillip Compeau, PhD, Program Director & Assistant Dept. Head
Location: GHC 7403

Tara Seman, Academic Program Manager
Location: GHC 7721
cbd.cmu.edu (<http://cbd.cmu.edu>)

Bachelor of Science in Computational Biology

Success in computational biology requires significant technical knowledge of fundamental computer science as well as a broad biological intuition and general understanding of experimental biology. However, most importantly, it requires students who can integrate their knowledge by making connections between the two fields.

There is significant industry demand for excellent computational biology students, in biotech, pharmaceuticals, and biomedical research. Both established companies and startups struggle to find employees with the correct skillset, and our students will be able to take advantage of the fact that an undergraduate computational biology major has the rigorous training required to handle the challenges of modern research that is not provided by any of our peer institutions.

Students in the B.S. program in Computational Biology are expected to acquire the following skills upon graduation:

- Understand the fundamentals of single and multi-variable calculus, as used to construct models of biological systems.
- Construct their own logical mathematical proofs and later apply these proof techniques to theorems in algorithms and theoretical computer science.
- Obtain a firm grounding in probability and statistics necessary for interpretation of biomedical research results.
- Apply the fundamentals of modern chemistry and physics to biological molecules.
- Learn the principles of organization of biological systems on the cellular and molecular level.
- Interpret the connection of the principles of inheritance to the molecular level.
- Understand the relationship between macro and micro in terms of biological structure and function and the connection to metabolic pathways.
- Produce sound, stable, well-organized computer programs that scale well on large datasets.
- Understand the theoretical basis of modern computer science and integrate the inherent limitations of any computing system.
- Design algorithms based on efficient data structures to a variety of computational contexts to meet specified goals.
- Apply machine learning methods by which computers can “learn” from experience and apply these methods to genomic and biomedical data.
- Become familiar with structured biological databases and computational tools for operating on these databases.
- Construct mathematical/computational models of biological systems at differing scales and analyze the strengths and weaknesses of these models.
- Learn the fundamental laboratory techniques used in modern cell and molecular biology as well as the influence of computational methods on experimental design.
- Acquire a skillset of canonical algorithms applied in modern biological research and understand how these algorithms are applied to solve biological problems.
- Gain fluency in contemporary biomedical research topics and be able to interpret primary research results in computational biology.
- Understand the role of computation in biotechnology, pharmaceutical development, and medicine.

Degree Requirements

(students entering Fall 2023)

Students completing the Bachelor of Science in Computational Biology follow certain policies that apply to all SCS students; please consult the SCS policies page (p. 678) for a complete listing of these expectations.

Students must complete a **minimum of 360 units** for the degree in computational biology.

Mathematics/Statistics Core

| | | |
|--------------------|--|-----------|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 15-151 | Mathematical Foundations for Computer Science (or 21-127/21-128 if not offered) | 12 |
| 36-218 | Probability Theory for Computer Scientists (Students taking 15-259 should take 36-326 or 15-260 instead. 15-260 is only open to students who have taken 15-259.) | 9 |
| or 36-226 | Introduction to Statistical Inference | |
| or 36-326 | Mathematical Statistics (Honors) | |
| or 36-235 | Probability and Statistical Inference I | |
| or 15-260 | Statistics and Computing | |
| 21-241 | Matrices and Linear Transformations | 10 |
| or 21-242 | Matrix Theory | |
| Total Units | | 51 |

General Science Core

| | | |
|--------------------|---|-----------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| Total Units | | 22 |

Biological Core

| | | |
|--------------------|--|-----------|
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| 03-232 | Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.) | 9 |
| or 03-231 | Honors Biochemistry | |
| 03-320 | Cell Biology | 9 |
| Total Units | | 37 |

Computer Science Core

| | | |
|--------------------|--|-----------|
| 07-128 | First Year Immigration Course (This course may be replaced by 03-201 or 03-202 if and only if 07-128 is not offered) | 1 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| or 15-351 | Algorithms and Advanced Data Structures | |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| Total Units | | 49 |

Computational Biology Core

| | | |
|--------------------|--|-----------|
| 02-251 | Great Ideas in Computational Biology | 12 |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | 12 |
| or 02-262 | Computation and Biology Integrated Research Lab | |
| 02-402 | Computational Biology Seminar | 3 |
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| Total Units | | 48 |

Major Electives

| | | |
|--------------------|---|--------------|
| 02-3xx | Computational Biology Electives at 300 level or above | 18-24 |
| 03-3xx | Biology Electives at 300 level or above (09-217 or 42-202 also count as biology electives) | 9-12 |
| xx-2xx | School of Computer Science Electives at 200 level or above, at least 9 units each. 15-150 is an acceptable 100-level course counting in this category, but the following exceptions are not allowed in this category: 02-201, 02-223, 02-250, 02-261, 02-262, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. | 18-24 |
| Total Units | | 45-60 |

Humanities & Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 680).

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

| | | |
|--------|-----------------------------|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
|--------|-----------------------------|---|

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements

| | |
|---------------------------------------|------------|
| Area | |
| Math/Stats Core | 39 |
| General Science Core | 22 |
| Biological Core | 36 |
| Computer Science Core | 47 |
| Computational Biology Core | 48 |
| Major Electives | 45-60 |
| General Education (Humanities & Arts) | 63 |
| Computing at Carnegie Mellon | 3 |
| Remaining Units | 42-57 |
| Total Units | 360 |

Sample Course Sequence

The following is an example four-year course sequence for computational biology majors, assuming the student has credit for one semester of calculus. Note that our suggested courses during the first year fall are aligned with the sample course sequence for Computer Science majors

(<https://www.csd.cs.cmu.edu/content/sample-undergraduate-course-sequence/>). All students interested in computational biology should take 03-151 (Honors Modern Biology) in their first fall and 02-251 (<http://cbd.cmu.edu/education/courses-offered/02-251-great-ideas-in-comp-bio.html>) (Great Ideas in Computational Biology) in their first spring.

Some suggestions listed below are quite flexible. For example, physics and chemistry can be taken at any point in the student's first three semesters, and some of the computer science courses below can be replaced by other courses within the School of Computer Science, depending on a student's individual interests.

Other courses, such as cell biology, biochemistry, computational genomics, and biological modeling and simulation, are only offered in either the fall or the spring.

We discuss a tailored plan with our majors to ensure that courses are taken at the appropriate times, while affording each student the flexibility to explore their other interests at CMU.

Note: Before you arrive at CMU, you will take 99-101 Computing at Carnegie Mellon and 15-051, a Discrete Math primer, in your own time. These short courses are provided to incoming students for free.

| First-Year | | Second-Year | |
|---|---|---|---|
| Fall | Spring | Fall | Spring |
| 07-128 First Year Immigration Course | 02-251 Great Ideas in Computational Biology | 02-261 Quantitative Cell and Molecular Biology Laboratory | 02-xxx Computational Biology Elective |
| 15-112 Fundamentals of Programming and Computer Science | 15-122 Principles of Imperative Computation | 21-241 Matrices and Linear Transformations | 15-251 Great Ideas in Theoretical Computer Science |
| 15-131 Great Practical Ideas for Computer Scientists | 09-105 Introduction to Modern Chemistry I | 33-121 Physics I for Science Students | 03-232 Biochemistry I |
| 15-151 Mathematical Foundations for Computer Science | 21-259 Calculus in Three Dimensions | 36-218 Probability Theory for Computer Scientists | 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis |
| 03-151 Honors Modern Biology | 76-101 Interpretation and Argument | 15-150 Principles of Functional Programming | xx-xxx Humanities and Arts Elective |
| 21-122 Integration and Approximation | | | |
| Third-Year | | Fourth-Year | |
| Fall | Spring | Fall | Spring |
| 02-512 Computational Methods for Biological Modeling and Simulation | 02-402 Computational Biology Seminar | 02-xxx Computational Biology Elective | xx-xxx Humanities and Arts Elective |
| 03-320 Cell Biology | 02-510 Computational Genomics | xx-xxx Humanities and Arts Elective | xx-xxx Free Elective |
| 10-315 Introduction to Machine Learning (SCS Majors) | 03-xxx Biology Elective | xx-xxx Free Elective | xx-xxx Free Elective |
| 15-210 Parallel and Sequential Data Structures and Algorithms | 15-451 Algorithm Design and Analysis | xx-xxx Free Elective | xx-xxx Free Elective |
| xx-xxx Humanities and Arts Elective | xx-xxx Humanities and Arts Elective | | |

Additional Major in Computational Biology

The Additional Major in Computational Biology is designed for undergraduate students wishing to study computational biology as a second field of study at Carnegie Mellon University in addition to their primary major.

The additional major is open to all students who complete the prerequisite coursework listed below, with the requirement that a student from outside SCS must have a 3.0 overall QPA when applying.

To prevent double-counting, students must complete at least seven courses of at least 9 units each as part of the additional major in computational biology (not including pre-requisites) that are unique to the additional major.

Students interested in the Additional Major in Computational Biology should contact the Computational Biology Undergrad Program Director.

Prerequisite Courses

| | | |
|-----------|---------------------------------------|----|
| 02-250 | Introduction to Computational Biology | 12 |
| or 02-251 | Great Ideas in Computational Biology | |

| | | |
|--------------------|---|-----------|
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 15-122 | Principles of Imperative Computation | 10 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| or 21-127 | Concepts of Mathematics | |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| Total Units | | 64 |

Mathematics/Statistics Core

| | | |
|--------------------|--|-----------|
| 36-218 | Probability Theory for Computer Scientists | 9 |
| or 36-226 | Introduction to Statistical Inference | |
| or 36-326 | Mathematical Statistics (Honors) | |
| or 36-235 | Probability and Statistical Inference I | |
| or 15-260 | Statistics and Computing | |
| 21-241 | Matrices and Linear Transformations | 10 |
| or 21-242 | Matrix Theory | |
| Total Units | | 19 |

General Science Core

| | | |
|--------------------|---|-----------|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | |
| 33-121 | Physics I for Science Students | 12 |
| or 33-141 | Physics I for Engineering Students | |
| Total Units | | 22 |

Biological Core

| | | |
|--------------------|---|-----------|
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| or 03-220 | Genetics | |
| 03-232 | Biochemistry I (Students taking 03-231, including pre-med students, will take organic chemistry as a prerequisite, which will satisfy a biology elective requirement.) | 9 |
| or 03-231 | Honors Biochemistry | |
| 03-320 | Cell Biology | 9 |
| Total Units | | 27 |

Computer Science Core

| | | |
|--------------------|---|-----------|
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| or 15-351 | Algorithms and Advanced Data Structures | |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| Total Units | | 36 |

Computational Biology Core

| | | |
|--------------------|--|-----------|
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | 12 |
| or 02-262 | Computation and Biology Integrated Research Lab | |
| 02-402 | Computational Biology Seminar | 3 |
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| Total Units | | 36 |

Major Electives

| | | |
|--------|--|-------|
| 02-3xx | Computational Biology Electives at 300 level or above | 18-24 |
| 03-3xx | Biology Electives at 300 level or above (09-217 or 42-202 also count as biology electives) | 9-12 |

| | | |
|--------|---|-------|
| xx-2xx | School of Computer Science Electives at 200 level or above, at least 9 units each. 15-150 is an acceptable 100-level course counting in this category, but the following exceptions are not allowed in this category: 02-201, 02-223, 02-250, 02-261, 02-262, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. | 18-24 |
|--------|---|-------|

Total Units **45-60**

General Education (Humanities & Arts)

For specific courses that may be used to satisfy each elective, please consult the General Education Requirements for your primary major.

Computational Biology Minor

SCS Majors: Please see the Computational Biology Concentration (p. 768)

Phillip Compeau, PhD, *Director*
Tara Seman, *Program Manager*

The computational biology minor is open to students in any major of any college at Carnegie Mellon outside the School of Computer Science.

The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in biological sciences that are central to computational biology.

Students are encouraged to declare the minor as early as possible in their undergraduate careers and in all cases before their final semester so that the minor advisor can provide advice on their curriculum.

Why Minor in Computational Biology?

Computational Biology is concerned with solving biological and biomedical problems using mathematical and computational methods. It is recognized as an essential element in modern biological and biomedical research. There have been fundamental changes in biology and medicine over the past two decades due to spectacular advances in high throughput data collection for genomics, proteomics and biomedical imaging. The resulting availability of unprecedented amounts of biological data demands the application of advanced computational tools to build integrated models of biological systems, and to use them to devise methods of prevent or treat disease. Computational Biologists inhabit and expand the interface of computation and biology, making them integral to the future of biology and medicine.

Policy on Double Counting

No more than two courses may be double counted with your major's core requirements. Courses in the minor may not be counted towards another SCS minor. Consult the minor advisor for more information.

Curriculum Overview

The minor in computational biology requires a total of five courses: 3 core courses, 1 biology elective, and 1 computational biology elective, for a **total of at least 45 units**.

Prerequisites

| | | |
|--|--|-------|
| Students must take both of the following courses as prerequisites: | | Units |
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Core Classes

Students must take both of the following courses:

| | | |
|-----------|---|------|
| 02-250 | Introduction to Computational Biology | 12 |
| or 02-251 | Great Ideas in Computational Biology | |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory (03-343 Experimental Techniques in Molecular Biology may be substituted for 02-261 with permission of the minor advisor; 03-116 may be used to replace 02-261 if and only if the latter is not offered) | 9-12 |

or 02-262 Computation and Biology Integrated Research Lab

Students must take one of the following courses:

| | | |
|--------|--|----|
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |

Biology Elective

Please select one of the following courses:

| | | |
|--------|--|----|
| 03-220 | Genetics | 9 |
| 03-221 | Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | 9 |
| 03-231 | Honors Biochemistry | 9 |
| 03-232 | Biochemistry I | 9 |
| 03-320 | Cell Biology | 9 |
| 03-327 | Evolutionary Bioinformatics: Trees, Sequences and the Comparative Method | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-439 | Introduction to Biophysics | 10 |
| 03-442 | Molecular Biology | 9 |
| 42-202 | Physiology | 9 |

Computational Biology Elective

Please select one of the following courses:

| | | |
|--------|--|------|
| 02-xxx | Any 02-xxx listed course 02-300 or above | 9-12 |
|--------|--|------|

Computer Science Program

Srinivasan Seshan, Department Head, Computer Science
Location: GHC 7019

Mark Stehlik, Program Director, Assistant Dean for Outreach
Location: GHC 6205

Amy Weis, Program Coordinator, CS Undergraduate Office
Location: GHC 4115
www.csd.cs.cmu.edu (<http://www.csd.cs.cmu.edu>)

The B.S. program in Computer Science combines a solid core of Computer Science courses with the ability to gain additional depth through a required minor in a second subject or a concentration in a computing area. In addition, the curriculum provides breadth through numerous choices for science, engineering, humanities and fine arts courses. As computing is a discipline with strong links to many fields, this provides students with unparalleled flexibility to pursue allied (or non-allied) interests.

Students apply to, and are directly admitted into, the School of Computer Science. Admitted students may choose to pursue an undergraduate degree in Computer Science and, upon successful completion, are awarded a Bachelor of Science in Computer Science. Suitably prepared students from other Carnegie Mellon colleges are eligible to apply for internal transfer to the School of Computer Science and will be considered for transfer if grades in core CS requirements are sufficiently high and space is available.

Students in the B.S. program in Computer Science are expected to acquire the following skills upon graduation:

- Identify, use, design, develop and analyze appropriate abstractions and algorithms to solve problems while being able to prove the algorithm's performance and correctness across a variety of metrics (e.g., time, space, parallel vs. sequential implementation, computability).
- Implement solutions to problems in domains such as artificial intelligence, graphics and sound, software engineering, and human-computer interaction, by applying the fundamentals of those areas to create solutions to current problems while being exposed to research developments that will enable them to adapt as the technology changes.
- Reason about and implement programs in various programming languages and paradigms
- Describe, specify, and develop large-scale, open-ended software systems subject to constraints such as performance and/or resource issues
- Communicate technical material effectively to technical and non-technical audiences
- Work both individually and in teams
- Recognize the social impact of computing and the attendant responsibility to consider the legal, moral and ethical implications of computing technologies.

Due to the tremendous number of ongoing research projects within the School, many students obtain part-time or summer jobs, or receive independent study credit, working on research while pursuing their undergraduate degree. Students seeking a research/graduate school career may pursue an intensive course of research, equivalent to four classroom courses, culminating in the preparation of a senior research thesis.

SCS also offers a B.S. degree in Artificial Intelligence, a B.S. degree in Computational Biology, a B.S. degree in Human-Computer Interaction, and a Bachelor's Degree in Computer Science and the Arts (jointly with the College of Fine Arts). More detail about the Artificial Intelligence major, the Computational Biology major and the Computer Science and the Arts program is available in separate sections of the Undergraduate Catalog. SCS offers additional majors in Computer Science (for non-CS majors), Human-Computer Interaction, and Robotics, and minors in Computational Biology, Computer Science (for non-CS majors), Human-Computer Interaction, Language Technologies, Machine Learning, Neural Computation, Robotics, and Software Engineering. Information about additional majors and minors in SCS besides those in Computer Science are listed in a separate section in the Undergraduate Catalog.

Computer Science

| Computer Science Core (all of the following): | | Units |
|---|---|-------|
| 07-128 | First Year Immigration Course | 3 |
| 15-122 | Principles of Imperative Computation (students without credit or a waiver for 15-112, Fundamentals of Programming and Computer Science, must take 15-112 before 15-122) | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |

One Artificial Intelligence elective (min. 9 units). Students will be able to tackle complex, real-world problems using techniques from Artificial Intelligence, including symbolic and probabilistic reasoning, machine learning, optimization, and perception.

| | | |
|--|---|----|
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-485 | Introduction to Deep Learning | 9 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| 16-385 | Computer Vision | 12 |
| others as designated by the CS Undergraduate Program | | |

One Domains elective (min. 9 units). Students will gain expertise in fundamental principles from a larger domain of computer science not already represented by other constrained categories, currently logic and languages, systems, and artificial intelligence (which includes machine learning, language technologies, and robotics). Students will be able to apply theoretical and computational techniques from the Computer Science core to an introductory study of another major subarea of Computer Science.

| | | |
|--|--|----|
| 02-251 | Great Ideas in Computational Biology | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 11-324 | Human Language for Artificial Intelligence | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 15-330 | Introduction to Computer Security | 12 |
| 15-455 | Undergraduate Complexity Theory | 9 |
| 15-462 | Computer Graphics | 12 |
| 17-313 | Foundations of Software Engineering | 12 |
| others as designated by the CS Undergraduate Program | | |

One Logics/Languages elective (min. 9 units). Students will master techniques for rigorous, formal reasoning about programs or systems, rooted in their logical foundations.

| | | |
|--|---|----|
| 15-312 | Foundations of Programming Languages | 12 |
| 15-314 | Programming Language Semantics | 12 |
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-317 | Constructive Logic | 9 |
| 15-414 | Bug Catching: Automated Program Verification | 9 |
| 15-424 | Logical Foundations of Cyber-Physical Systems | 12 |
| 17-355 | Program Analysis | 12 |
| 17-363 | Programming Language Pragmatics | 12 |
| 80-413 | Category Theory | 9 |
| others as designated by the CS Undergraduate Program | | |

Curriculum - B.S. in Computer Science

The following requirements are for students entering Fall 2023.

One Software Systems elective (min. 12 units). Students will:

1. be able to describe how the properties of modern hardware (e.g., processor architecture, networks, storage) influence the design and implementation of software systems, such as through reasoning about concurrency and performance.
2. be able to analyze failures and / or resource limitations of physical systems and plan for their mitigation or management.
3. be able to develop abstractions based on lower-level primitives to manage the failures or other difficulties inherent in working with hardware.
4. demonstrate their learning through significant project / system implementations, requiring both course-specific knowledge as well as general system-building skills (i.e., not just programming, but also design, debugging, testing, etc.). The programming tasks together constitute a significant fraction of the course grade (e.g., 40% or more).

| | | |
|--|--|----|
| 15-410 | Operating System Design and Implementation | 15 |
| 15-411 | Compiler Design | 15 |
| 15-418 | Parallel Computer Architecture and Programming | 12 |
| 15-440 | Distributed Systems | 12 |
| 15-441 | Networking and the Internet | 12 |
| 15-445 | Database Systems | 12 |
| others as designated by the CS Undergraduate Program | | |

Two Computer Science electives: Units
 18
 These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)

Mathematics

All of the following Mathematics courses:

| | | |
|-----------|---|----|
| 15-151 | Mathematical Foundations for Computer Science (if not offered, substitute 21-127 or 21-128) | 12 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |

Plus one of the following four Probability choices:

| | | |
|---------------|---|----|
| 15-259 | Probability and Computing | 12 |
| 21-325 | Probability | 9 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference (must take both courses in this sequence to satisfy requirement) | 18 |

Technical Communication

Learning Objectives:

Audience

Students will be able to analyze the audience or audiences of a work: who the stakeholders are, what those stakeholders are trying to accomplish, and how persuasive communication can help students achieve their goals.

Written Mechanics

Students will practice developing their professional writing voice, paying attention to spelling, grammar, style, and the use of visual information.

Adaptation

Students will be able to adapt expert-level information for a general audience, across textual, graphical, and oral presentation.

Genres/Templates

Students will practice developing information in a variety of communication contexts, connecting areas of content in their own voice, and leading

the reader through a cogent sequence of ideas while working within the constraints of a particular genre or template.

Peer Review

Students will practice reading and revising the work of themselves and their peers.

Oral Presentation Mechanics

Students will prepare for the real-time act of presenting to an audience, including delivery, practice, venue setup, and managing presentation support (slides, props, etc.).

Oral Presentation Development

Students will explore formal and informal modes of communication, selecting, organizing and explaining information for a real-time audience, and increasing clarity with use of structure and style.

Group Work

Students will practice skills to help them work as a team, stay on track, and produce a group deliverable.

| | | |
|--------------------------------------|---|-------|
| One Technical Communications course: | | Units |
| 07-300 | Research and Innovation in Computer Science | 9 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 76-270 | Writing for the Professions | 9 |

Science and Engineering

All candidates for the bachelor's degree in Computer Science must complete a minimum of 36 units offered by the Mellon College of Science and/or the College of Engineering (CIT). These courses offer students an opportunity to explore scientific and engineering domains that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 680).

Humanities and Arts

All candidates for the bachelor's degree in Computer Science must complete a minimum of 63 units offered by the College of Humanities & Social Sciences and/or the College of Fine Arts. Some courses from the Tepper School of Business also qualify for this requirement. These courses offer students breadth in their education and perspectives and provide students with a better appreciation of social, artistic, cultural, political and economic issues that can influence their effectiveness as computer scientists upon graduation.

Requirements for this component of the degree are listed under the SCS main page under General Education Requirements (p. 680).

Required Minor or Concentration

Students completing the bachelor's degree in Computer Science must complete either a minor outside of SCS or a concentration within SCS. A minor is a sequence of (typically 5-6) courses within a particular department to give students a core of a specific discipline but not an entire major of study. Refer to the sections for other CMU colleges for details about available non-SCS minors. An SCS concentration is a sequence of (typically 4-5) courses within an SCS department to give students further depth in specific areas of research important to SCS. SCS concentrations are available only to SCS students and assume that these students have a significant core knowledge in Computer Science including 15-210, 15-213 and 15-251. See the SCS Concentrations section for a list of available concentrations and their requirements. Completion of an additional major (or dual degree) also satisfies this requirement. Students should consult with their academic advisor to plan for their desired minor or concentration starting in the sophomore year.

Double Counting

In general, courses taken in satisfaction of the minor or additional major may also count toward any general education category in the CS major (i.e. courses outside of the Computer Science and Mathematics requirements). Double counting toward Computer Science and Mathematics courses in the CS major is strictly limited and depends on the chosen minor (or additional major). In general, students may double count at most 5 of the 12 core Computer Science requirements toward all other declared additional majors and minors. Additional majors and minors have their own double counting rules as well. Consult with a CS undergraduate advisor and an advisor from the department of the minor (or additional major) for specific restrictions on double counting.

Computing @ Carnegie Mellon (1 course)

The following course is required of all students to familiarize them with the campus computing environment:

99-101 Computing @ Carnegie Mellon 3

Free Electives

A free elective is any Carnegie Mellon course. However, a maximum of nine (9) units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements.

Summary of Degree Requirements:

| Area | Courses | Units |
|---|---------|------------|
| Computer Science (core courses, constrained electives, and SCS electives) | 12 | 125 |
| Mathematics | 6 | 58 |
| Technical Communication | 1 | 9 |
| Science/Engineering | 4 | 36 |
| Humanities/Arts | 7 | 63 |
| Minor or Concentration Requirement/Free electives | Varies | 63 |
| Computing @ Carnegie Mellon | 1 | 3 |
| First Year Seminar | 1 | 3 |
| | | 360 |

Sample Course Sequence

The sample given below is for a student who already has credit for introductory programming and one semester of calculus. Students with credit for two semesters of calculus may start with a more advanced math class (e.g. 21-241) in their first year. Students with no credit for introductory programming and/or one semester of calculus will take 15-112 and/or 21-120 in their first semester and shift a few courses to later semesters after consulting with their academic advisor; these students should still be able to complete their degree in four years. It is recommended that students keep their academic load lighter for their Senior Fall semester to account for offsite job interviews or for their Senior Spring semester to account for visits to graduate schools.

Freshman Year:

| Fall | Units |
|--|-----------|
| 07-128 First Year Immigration Course | 3 |
| 07-131 Great Practical Ideas for Computer Scientists (optional, not required for CS major) | 2 |
| 15-122 Principles of Imperative Computation | 12 |
| 15-151 Mathematical Foundations for Computer Science (if not offered, substitute 21-127) | 12 |
| 21-122 Integration and Approximation | 10 |
| 76-101 Interpretation and Argument | 9 |
| 99-101 Computing @ Carnegie Mellon | 3 |
| | 51 |

| Spring | Units |
|---|-----------|
| 15-150 Principles of Functional Programming | 12 |
| 15-213 Introduction to Computer Systems | 12 |
| 21-259 Calculus in Three Dimensions | 10 |
| xx-xxx Science/Engineering Course | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| | 52 |

Sophomore Year:

| Fall | Units |
|---|-----------|
| 15-210 Parallel and Sequential Data Structures and Algorithms | 12 |
| 21-241 Matrices and Linear Transformations | 11 |
| xx-xxx Science/Engineering Course | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| | 50 |

| Spring | Units |
|--|-----------|
| 15-251 Great Ideas in Theoretical Computer Science | 12 |
| xx-xxx Computer Science: Domains Elective* | 9 |
| xx-xxx Probability Course* | 9 |
| xx-xxx Science/Engineering Course | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| | 48 |

Junior Year:

| Fall | Units |
|--|-----------|
| 15-451 Algorithm Design and Analysis | 12 |
| xx-xxx Computer Science: Logic/Languages Elective* | 9 |
| xx-xxx Technical Communications Course* | 9 |
| xx-xxx Minor Requirement / Free Elective | 10 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| | 49 |

| Spring | Units |
|--|-----------|
| 15-xxx Computer Science: Systems Elective* | 12 |
| xx-xxx Computer Science: Artificial Intelligence Elective* | 9 |
| xx-xxx Science/Engineering Course | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| | 48 |

Senior Year:

| Fall | Units |
|--|-----------|
| xx-xxx School of Computer Science Elective | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| | 36 |

| Spring | Units |
|--|-----------|
| xx-xxx School of Computer Science Elective | 9 |
| xx-xxx Humanities and Arts Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| xx-xxx Minor Requirement / Free Elective | 9 |
| | 36 |

Minimum number of units required for the degree: 360

*The flexibility in the curriculum allows many different schedules, of which the above is only one possibility. Some elective courses are offered only once per year (Fall or Spring). Constrained electives (probability, logic/languages, software systems, artificial intelligence and domains) may be taken in any order and in any semester if prerequisites are met and seats are available. Constrained electives are shown in the specific semesters in the schedule above as an example only. Students should consult with their academic advisor to determine the best elective options depending on course availability, their academic interests and their career goals.

Undergraduate Research Thesis

CS majors may use the SCS Honors Research Thesis as part of their degree. The SCS Honors Undergraduate Research Thesis (07-599) typically starts in the fall semester of the senior year, and spans the entire senior year. Students receive a total of 36 units of academic credit for the thesis work, 18 units per semester. Up to 18 units can be counted toward CS elective requirements (9 per semester for 2 semesters maximum). Students interested in research may also consider using Research and Innovation in Computer Science (07-300, 9 units) as their technical communications requirement in their junior year since this course will introduce students to various research projects going on in the School of Computer Science that may lead to a senior thesis. This course leads to a subsequent Research Practicum in Computer Science (07-400, 12 units) that allows students to complete a small-scale research study or experiment and present a research poster. Students who use 15-400 to start their senior thesis can use these units toward the required 36 units.

For more information about the SCS Honors Research Thesis, refer to the SCS Honors Research Thesis (p. 683) section for learning objectives, application requirements and expected outcomes.

Dual Degree in Computer Science

Students wishing to pursue a Dual Degree in Computer Science are required to apply in the same way as students wishing to transfer into the Computer Science major. Details are given in the SCS Policies section. Besides the student's primary degree requirements, a student accepted for Dual Degree in CS is required to complete at least 450 units in total and meet all requirements for the CS major including all general education requirements (humanities/arts and science/engineering). Dual degree students do not need to complete 15-128, and these students will replace 15-151 with either 21-127 or 21-128. Since the CS major requires at least a minor or concentration in another area, the student's primary major will substitute for this requirement. Note that the primary major must be completed prior to or at the same time as the dual degree in CS to satisfy the minor requirement; a dual degree in CS cannot be certified if the primary degree is not completed. Students should consult with the Assistant Dean in the CS Undergraduate Office and/or their CS academic advisor to review all requirements, once approved.

Double-Counting Restriction

Students pursuing a Dual Degree in Computer Science must complete all requirements for the CS primary major (except 15-128 which is not required and 15-151 which will be replaced with 21-127 or 21-128). In addition, at most 5 of the 12 computer science requirements can double count with all other declared majors and minors. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Assistant Dean or Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Additional Major

Students interested in pursuing an additional major in Computer Science should first consult with the Program Coordinator in the CS Undergraduate Office. Students are expected to complete the requirements for the CS minor first before continuing on to the additional major. Completion of the CS additional major requires 12 computer science courses (not including 15-110 and 15-112 if needed), 5 mathematics courses, and 1 technical communication course. Students are expected to complete all courses for the additional major with an average QPA of 3.0 or higher.

Declaration for the additional major is allowed only after all math requirements are completed or in progress, and at least 9 of the 12 CS requirements (core and electives) are completed or in progress. Due to high demand, seats in upper-level CS courses are not guaranteed for additional majors so students should plan to be flexible in selecting constrained and general electives. Acceptance to complete a Computer Science additional major is not guaranteed and depends on student performance and seat availability.

The following courses are required for the Additional Major in Computer Science:

Computer Science requirements (12 courses):

| Core courses (all are required): | | Units |
|---|---|-------|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| One Artificial Intelligence elective (minimum 9 units). Students will be able to tackle complex, real-world problems using techniques from Artificial Intelligence, including symbolic and probabilistic reasoning, machine learning, optimization, and perception. | | Units |
| 10-315 | Introduction to Machine Learning (SCS Majors) (or 10-301) | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-485 | Introduction to Deep Learning | 9 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 16-384 | Robot Kinematics and Dynamics | 12 |

| | | |
|--|-----------------|----|
| 16-385 | Computer Vision | 12 |
| others as designated by the CS Undergraduate Program | | |

One Domains elective (minimum 9 units). Students will gain expertise in fundamental principles from a larger domain of computer science not already represented by other constrained categories, currently logic and languages, systems, and artificial intelligence (which includes machine learning, language technologies, and robotics). Students will be able to apply theoretical and computational techniques from the Computer Science core to an introductory study of another major subarea of Computer Science.

| | | |
|--|--|----|
| 02-251 | Great Ideas in Computational Biology | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| 11-324 | Human Language for Artificial Intelligence | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 15-330 | Introduction to Computer Security | 12 |
| 15-455 | Undergraduate Complexity Theory | 9 |
| 15-462 | Computer Graphics | 12 |
| 17-313 | Foundations of Software Engineering | 12 |
| others as designated by the CS Undergraduate Program | | |

One Logic & Languages elective (minimum 9 units). Students will master techniques for rigorous, formal reasoning about programs or systems, rooted in their logical foundations.

| | | |
|--|---|----|
| 15-312 | Foundations of Programming Languages | 12 |
| 15-314 | Programming Language Semantics | 12 |
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-317 | Constructive Logic | 9 |
| 15-414 | Bug Catching: Automated Program Verification | 9 |
| 15-424 | Logical Foundations of Cyber-Physical Systems | 12 |
| 17-355 | Program Analysis | 12 |
| 17-363 | Programming Language Pragmatics | 12 |
| 80-413 | Category Theory | 9 |
| others as designated by the CS Undergraduate Program | | |

One Systems elective (minimum 12 units). Students will 1. be able to describe how the properties of modern hardware (e.g., processor architecture, networks, storage) influence the design and implementation of software systems, such as through reasoning about concurrency and performance. 2. be able to analyze failures and / or resource limitations of physical systems and plan for their mitigation or management. 3. be able to develop abstractions based on lower-level primitives to manage the failures or other difficulties inherent in working with hardware. 4. demonstrate their learning through significant project / system implementations, requiring both course-specific knowledge as well as general system-building skills (i.e., not just programming, but also design, debugging, testing, etc.). The programming tasks together constitute a significant fraction of the course grade (e.g., 40% or more).

| | | |
|--|--|----|
| 15-410 | Operating System Design and Implementation | 15 |
| 15-411 | Compiler Design | 15 |
| 15-418 | Parallel Computer Architecture and Programming | 12 |
| 15-440 | Distributed Systems | 12 |
| 15-441 | Networking and the Internet | 12 |
| 15-445 | Database Systems | 12 |
| others as designated by the CS Undergraduate Program | | |

Two Computer Science electives (minimum 18 units): These electives can be from any SCS department; 200-level or above, at least 9 units each (see exceptions below): Computer Science [15-], Computational Biology [02-], Human Computer Interaction [05-], Machine Learning [10-], Language Technologies [11-], Robotics [16-], and Software Engineering [17-]. (NOTE: The following undergraduate courses do NOT count as Computer Science electives: 02-201, 02-223, 02-250, 02-261, 11-423, 15-351, 16-223, 17-200, 17-333, 17-562. Some IDEATE courses and some SCS undergraduate and graduate courses might not be allowed based on course content. Consult with a CS undergraduate advisor before registration to determine eligibility for this requirement.)

Math requirements (minimum 5 courses):

| | | |
|-------------------------------|------------------------------------|-------|
| | | Units |
| All of the following courses: | | |
| 21-120 | Differential and Integral Calculus | 10 |

| | | |
|----------------------------|---|----|
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| Plus one of the following: | | |
| 15-259 | Probability and Computing | 12 |
| 21-325 | Probability | 9 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 36-226 | Introduction to Statistical Inference (for students already taking 36-219 or 36-225) | 9 |

Technical Communication requirement (1 course)

Learning Objectives:

Audience

Students will be able to analyze the audience or audiences of a work: who the stakeholders are, what those stakeholders are trying to accomplish, and how persuasive communication can help students achieve their goals.

Written Mechanics

Students will practice developing their professional writing voice, paying attention to spelling, grammar, style, and the use of visual information.

Adaptation

Students will be able to adapt expert-level information for a general audience, across textual, graphical, and oral presentation.

Genres/Templates

Students will practice developing information in a variety of communication contexts, connecting areas of content in their own voice, and leading the reader through a cogent sequence of ideas while working within the constraints of a particular genre or template.

Peer Review

Students will practice reading and revising the work of themselves and their peers.

Oral Presentation Mechanics

Students will prepare for the real-time act of presenting to an audience, including delivery, practice, venue setup, and managing presentation support (slides, props, etc.).

Oral Presentation Development

Students will explore formal and informal modes of communication, selecting, organizing and explaining information for a real-time audience, and increasing clarity with use of structure and style.

Group Work

Students will practice skills to help them work as a team, stay on track, and produce a group deliverable.

| | | |
|--------------------------------------|---|-------|
| One Technical Communications course: | | Units |
| 07-300 | Research and Innovation in Computer Science | 9 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 76-270 | Writing for the Professions | 9 |

Double-Counting Restriction

Students pursuing an Additional Major in Computer Science must complete all requirements listed above. In addition, at most 5 of the 12 computer science requirements can be double counted toward all other declared majors and minors. The mathematics and technical communication requirements can be double counted without restriction. Students, especially from interdisciplinary majors or with multiple majors or minors, are urged to consult with the Computer Science Program Director or the Undergraduate Program Coordinator in the CS Undergraduate Office to determine double-counting restrictions specific to their own situations.

Computer Science Minor

Students interested in pursuing a minor in Computer Science should first consult with the Program Coordinator in the CS Undergraduate Office after completion of the prerequisites, 15-122, 15-150 and with at least one of the 200-level required courses in progress. Students are expected to complete all courses for the minor with a C or higher (for a minor average QPA of 2.0 or higher).

The following courses are required for the Minor in Computer Science:

| | | |
|---|--|-------|
| Prerequisites: | | Units |
| 15-112 | Fundamentals of Programming and Computer Science (some students may need to take 15-110 prior to 15-112 for additional preparation) | 12 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| Computer Science core courses: | | |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| One of the following Computer Science core courses: | | |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Two additional Computer Science electives, of at least 9 units each:

| | |
|---|----|
| CS elective courses must be 15-213 or higher, at least 9-units each. 15-351 cannot be used. One course can be from any other SCS department besides the Computer Science Department, with prior approval. Note: Students who take 15-213/18-213 or 15-251 as part of another degree are required to replace that CS minor requirement with another CS elective (15-xxx) as defined above, for a total of 3 additional CS electives. | 18 |
|---|----|

Double-Counting Restriction

Students may double-count a maximum of 2 courses for the CS minor (not including the prerequisites) toward all other majors and minors. Students, especially from computing-related majors, interdisciplinary majors or with multiple majors or minors, are urged to consult with the Computer Science Program Director or the Undergraduate Program Coordinator in the CS Undergraduate Office to review double-counting restrictions specific to their own situations.

Human-Computer Interaction

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<https://www.hcii.cmu.edu/academics/hci-undergraduate> (<https://www.hcii.cmu.edu/academics/hci-undergraduate/>)

Undergraduate Major in HCI

In 2020, Carnegie Mellon University became one of the first universities worldwide to offer a primary major in Human-Computer Interaction (HCI). Students graduating from the HCI primary will have a unique perspective on how digital products and services impact humans, and also how they can be designed to have a positive impact.

About the B.S. in HCI

The Bachelor of Science in Human-Computer Interaction will produce HCI specialists who are technically skilled and adept at designing and prototyping interactive solutions with the latest digital technologies. Students graduating from the HCI primary will have a unique perspective on how digital products and services impact humans, and also how they can be designed to have a positive impact.

Students in this major will have a strong Computer Science core of programming, algorithms, systems and mathematical foundations, just like the other undergraduate majors in SCS. They will specialize by making core elements of human-computer interaction the primary focus of their upper-level classes, and can explore a large range of HCI topics in greater depth through their elective choices. In the final capstone project course, they will work as part of an interdisciplinary student team to produce innovative digital solutions for a problem presented by a client.

Responding to the Demand for HCI in Tech

Our corporate partners spoke of the need for competitive entry-level professionals who can enter the workforce with a solid understanding of HCI. This technical program will prepare graduates to understand and create innovative services, systems and applications that serve all people. Students will have the opportunity to design for a range of digital technologies, including web, mobile, IoT, VR, AR, sensors, fabrication, gadgets and more.

There is also a need for HCI practitioners with a "T-shaped person" knowledgebase. That is, professionals who exhibit broad knowledge and diverse technical skills, as well as a valuable focus in a specialization area. HCI majors will build a broad foundational knowledge in computing, mathematics and statistics; development skills for digital and interactive technologies; and experience with methods of rapid prototyping, all of which will help them to collaborate with their peers in related fields.

Opportunities for B.S. in HCI Grads

Graduates with this rigorous background will serve key roles in the tech industry. B.S. in HCI graduates will be poised to take on strategic roles at early stages of their careers, including Front End Engineer, Interaction Designer, Technical Product Manager and UX Engineer positions. HCI students aiming for research careers or graduate school can select a senior thesis option and conduct independent research work under the mentorship of HCI faculty.

Bachelor of Science in HCI Degree Requirements

The primary major in HCI supports students by preparing them with very strong technical knowledge, skills, and understanding. HCI majors must take a minimum of 360 units (35 courses) distributed as follows:

- CS Core: 5 courses + freshman immigration course
- Computing @ Carnegie Mellon: 3 units
- Mathematics and Statistics: 4 courses
- HCI Core: 6 courses
- HCI Electives: 4 courses
- HCI Capstone Project: 1 course
- Free Electives: 4 courses

- Science and Engineering: 4 courses
- Humanities and Arts (Gen Ed): 7 courses

Total: 35 courses

Computer Science Core (5 courses + immigration course)

| Prerequisite Courses | | Units |
|----------------------|--|-------|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 07-131 | Great Practical Ideas for Computer Scientists | 2 |

| Required Courses | | Units |
|------------------|--|-------|
| 07-128 | First Year Immigration Course | 3 |
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |

Mathematics and Statistics Core (4 courses)

| Prerequisite Course | | Units |
|---------------------|------------------------------------|-------|
| 21-120 | Differential and Integral Calculus | 10 |

| Required Courses | | Units |
|------------------|-------------------------------|-------|
| 21-122 | Integration and Approximation | 10 |
| 21-259 | Calculus in Three Dimensions | 10 |

Select one of the following courses:

| | | |
|--------|--|----|
| 15-259 | Probability and Computing | 12 |
| 21-325 | Probability | 9 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

Select one of the following courses:

| | | |
|--------|---|----|
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-401 | Modern Regression | 9 |

HCI Core (6 courses)

| Research & Evaluation Courses (2) | | Units |
|-----------------------------------|---------------------------------------|-------|
| 05-410 | User-Centered Research and Evaluation | 12 |

Select one:

| | | |
|--------|--|---|
| 36-202 | Methods for Statistics & Data Science | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 70-208 | Regression Analysis | 9 |

Ideation & Design Courses (2)

| | | |
|--------|---------------------------------|----|
| 05-360 | Interaction Design Fundamentals | 12 |
|--------|---------------------------------|----|

Select one:

| | | |
|--------|--|----|
| 05-361 | Advanced Interaction Design | 12 |
| 05-291 | Learning Media Design | 12 |
| 05-315 | Persuasive Design | 12 |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-418 | Design Educational Games | 12 |
| 05-452 | Service Design | 12 |
| 05-470 | Digital Service Innovation | 12 |

*Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor.

Technical Core (2)

| | | |
|--------|---|----|
| 05-380 | Prototyping Algorithmic Experiences | 15 |
| 05-431 | Software Structures for User Interfaces | 12 |

Psychology (1 course)

| Select one: | | Units |
|-------------|----------------------|-------|
| 85-211 | Cognitive Psychology | 9 |

| | | |
|--------|--|---|
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |
| 85-370 | Perception | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-421 | Language and Thought | 9 |
| 88-120 | Reason, Passion and Cognition | 9 |

Note: The Psychology course fulfills the Category 1: Cognition, Choice and Behavior requirement for HCI majors.

HCI Electives (4 courses)

| Design Elective (1) **Select a different course from that chosen under Ideation and Design HCI core (above) | Units |
|---|-------|
| 05-361 Advanced Interaction Design | 12 |
| 05-291 Learning Media Design | 12 |
| 05-315 Persuasive Design | 12 |
| 05-317 Design of Artificial Intelligence Products | 12 |
| 05-418 Design Educational Games | 12 |
| 05-452 Service Design | 12 |
| 05-470 Digital Service Innovation | 12 |

*Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor.

Technical Elective (1)

| | |
|--|----|
| 05-318 Human AI Interaction | 12 |
| 05-333 Gadgets, Sensors and Activity Recognition in HCI | 12 |
| 05-434 Machine Learning in Practice | 12 |
| 05-839 Interactive Data Science | 12 |
| 10-315 Introduction to Machine Learning (SCS Majors) | 12 |
| 11-411 Natural Language Processing | 12 |
| 15-281 Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-365 Experimental Animation | 12 |
| 15-388 Practical Data Science | 9 |
| 15-462 Computer Graphics | 12 |
| 15-464 Technical Animation | 12 |
| 15-466 Computer Game Programming | 12 |
| 15-494 Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-467 Human Robot Interaction | 12 |
| 17-428 Machine Learning and Sensing | 12 |
| 17-437 Web Application Development | 12 |
| 17-537 Artificial Intelligence Methods for Social Good | 9 |

*The remaining 2 electives can be chosen from the above lists or from the pre-approved list of HCI electives. Other options will require approval from the program director.

HCI Capstone Project (1 course)

| | |
|-------------------------------------|----|
| 05-571 Undergraduate Project in HCI | 12 |
|-------------------------------------|----|

Science & Engineering (4 courses)

Four courses in the domain of science and engineering are required, of which at least one must have a laboratory component and at least two must be from the same department. These courses typically come from the Mellon College of Science and the College of Engineering (CIT). Courses with a primary focus on programming, computation or mathematics are not acceptable for science or engineering courses. Requirements for this component of the degree are listed under the SCS main page under General Education Requirements.

Humanities & Arts (7 courses)

These requirements follow the SCS General Education requirements for Humanities & Arts. Requirements for this component of the degree are listed under the SCS main page under General Education Requirements. NOTE: The Psychology requirement of the HCI core will satisfy the General Education requirement for Category 1: Cognition, Choice & Behavior.

Free Electives (4 courses)

A free elective is any Carnegie Mellon course. However, a maximum of 9 units of Physical Education and/or Military Science (ROTC) and/or Student-Led (StuCo) courses may be used toward fulfilling graduation requirements. These could be used for optional Research Track or an optional minor or concentration.

Additional Major in Interdisciplinary HCI

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 www.hcii.cmu.edu (<http://www.hcii.cmu.edu/>)

OVERVIEW

Human-Computer Interaction (HCI) is a fast growing field devoted to the design, implementation, and evaluation of interactive computer-based technology. Examples of HCI products include intelligent computer tutors, wearable computers, social networking sites, and internet-connected personal digital assistants (PDAs). Constructing an HCI product is a cyclic, iterative process that has at least three stages: Design, Implementation, and Evaluation.

The Design stage involves principles of design and human behavior, the Implementation stage principles of computer science, and the Evaluation stage empirical research methods common to several disciplines. There are thus four topical areas to cover in this major: Human Behavior, Design, Implementation, and Evaluation. In slightly more detail, the major involves the following sorts of knowledge and skill:

Design

- Eliciting from the client, formulating, and articulating functional specifications
- Knowing how human factors and cognitive models should inform design
- Knowing the principles of, and having experience with, communication design
- Understanding how implementation constraints should inform design
- Incorporating evaluation results into iterated designs

Implementation Programming Skills

- Standard programming languages - e.g., C++, Java
- Rapid prototyping skills
- Computational literacy, i.e., knowledge sufficient for effective communication and decision making about:
 - interface construction tools and languages
 - multimedia authoring tools
 - data structures and algorithms
 - operating systems, platforms, etc.

Evaluation

- Experimental design
- Focus groups
- Surveys
- Usability testing (Cognitive walkthroughs, user models, heuristic evaluation, GOMS)
- Statistical analysis

There are over 45 courses relevant to these areas that are now offered by eight different departments in four different colleges at Carnegie Mellon (School of Computer Science, Dietrich College of Humanities and Social Sciences, College of Fine Arts, and Tepper School of Business).

ABOUT THE ADDITIONAL MAJOR

The Additional Major in Interdisciplinary Human-Computer Interaction (HCI) is available to current undergraduate students from any CMU college. Students maintain their primary major, and by adding an additional major in HCI, can explore multiple areas of study during their time at CMU. Applications to the additional major are processed once a year, in the spring (see below).

CURRICULUM

The following requirements are for students entering Fall 2023.

The Additional Major in Interdisciplinary Human-Computer Interaction (HCI) consists of 12 prerequisite and required courses.

Prerequisite Courses (4)

These courses do not need to be taken before applying to the additional major program. However, please note the required order sequence for two courses, listed below.

- Introductory statistics course, details below
- Psychology, details below
- A freshman-level programming course (details below) *must be completed before enrolling in the HCI core course 05-430 or 05-380*
- 05-360: Interaction Design for Human Computer Interaction *must be completed before enrolling in the HCI core course 05-361 Advanced Interaction Design*

| Prerequisites | | Units |
|--|--|-------|
| Psychology (Select one) | | |
| 85-211 | Cognitive Psychology | 9 |
| 85-241 | Social Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| Design | | |
| 05-360 | Interaction Design Fundamentals <small>Design majors do not need to take 05-360 as a prerequisite, since they learn similar material in other courses for their major.</small> | 12 |
| Statistics (Select one) | | |
| 36-200 | Reasoning with Data | 9 |
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference | 18 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-247 | Statistics for Lab Sciences | 9 |
| 70-207 | Probability and Statistics for Business Applications | 9 |
| Introduction to Programming (Select one) | | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-121 | Introduction to Data Structures | 10 |

HCI Core Courses (4)

The HCI core courses include the following required courses: (Prerequisite courses and the electives are not core courses.)

- 05-410: User-Centered Research & Evaluation (UCRE)
- 05-361: Advanced Interaction Design or another advanced Design course (see details below)
- 05-430: Programming Usable Interfaces (PUI) or 05-380: Prototyping Algorithmic Experiences (PAX) or 05-431: Software Structures for User Interfaces (SSUI)
- 05-571: Undergraduate Project in HCI (Capstone) *The Capstone course should be taken during the student's final spring semester.

| Core Courses | | Units |
|---|--|-------|
| 05-410 | User-Centered Research and Evaluation | 12 |
| Select one: | | |
| 05-361 | Advanced Interaction Design | 12 |
| 05-291 | Learning Media Design | 12 |
| 05-315 | Persuasive Design | 12 |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-418 | Design Educational Games | 12 |
| 05-452 | Service Design | 12 |
| 05-470 | Digital Service Innovation | 12 |
| *Some (but not all) special topics classes (05-499) might also count towards the advanced design class requirement. Please consult with an HCI undergraduate advisor. | | |
| Select one: | | |
| 05-430 | Programming Usable Interfaces | 15 |
| 05-380 | Prototyping Algorithmic Experiences | 15 |
| 05-431 | Software Structures for User Interfaces | 12 |
| Capstone | | |
| 05-571 | Undergraduate Project in HCI | 12 |

Special Notes for Design Majors

- Design majors do not need to take 05-360 Interaction Design for Human Computer Interaction as a prerequisite, since they learn similar material in other courses for their major.

Electives (4 courses)

HCI additional major students must take four HCI-related electives (9 units or more). Electives are intended to provide additional major students with advanced concepts and skills relevant to HCI or breadth of experience not available from their primary major. Given these goals, most electives will be 300-level courses or higher. Courses at the 100-level and 200-level in one's primary major will not count as electives, although the same course taken by a non-major may count (approval is still required).

Students can take electives in the HCII or courses relevant to HCI from many other departments on campus. All external electives are approved on a case-by-case basis.

All 05-xxx courses are pre-approved as HCI electives; however, core courses cannot double count as electives. See the HCII website for a list of current pre-approved electives: [https://www.hcii.cmu.edu/academics/hci-undergrad/electives/](https://www.hcii.cmu.edu/academics/hci-undergrad/electives)

Double Counting

Students may double count up to two (2) of the required core and elective courses (prerequisite courses do not apply to the double-counting rule) with their primary major.

Accelerated Master's Program (AMHCI)

The HCII currently offers a three semester (12-month), 15 course Masters in HCI. Undergraduates currently enrolled in the HCI major may apply for the Accelerated Masters program in the fall semester of their senior year. If admitted, students finish the masters degree the following fall semester.

Admission to the Additional Major

Because space is limited in the major's required courses, enrollment in the HCI additional major is currently limited. The admissions period occurs in spring semesters. For more details, see the website at <https://www.hcii.cmu.edu/academics/hci-undergrad/additional-major-hci/admissions> (<https://www.hcii.cmu.edu/academics/hci-undergrad/additional-major-hci/admissions/>).

Minor in Interdisciplinary HCI

The Minor in Interdisciplinary Human-Computer Interaction will give students core knowledge about techniques for building successful user interfaces, approaches for conceiving, refining, and evaluating interfaces that are useful and useable, and techniques for identifying opportunities for computational technology to improve the quality of people's lives. The students will be able to effectively collaborate in the design, implementation, and evaluation of easy-to-use, desirable, and thoughtful interactive systems. They will be

- Fieldwork for understanding people's needs and the influence of context
- Generative approaches to imagining many possible solutions such as sketching and "bodystorming"
- Iterative refinement of designs
- Basic visual design including typography, grids, color, and the use of images
- Implementation of interactive prototypes
- Evaluation techniques including discount and empirical evaluation methods

The HCI minor is targeted at undergraduates who expect to get jobs where they design and/or implement information technology-based systems for end users, as well as students with an interest in learning more about the design of socio-technical systems. It is appropriate for students with a major in Information Systems, as well as students in less software-focused majors, including Design, Architecture, Art, Business Administration, Psychology, Statistics, Decision Science, Mechanical Engineering, Electrical Engineering, English and many others in the university.

CURRICULUM

The following requirements are for students entering Fall 2023.

| Prerequisite (select one) | Units |
|---|-------|
| 15-110 Principles of Computing | 10 |
| 15-112 Fundamentals of Programming and Computer Science | 12 |
| 15-121 Introduction to Data Structures | 10 |
| 15-104 Introduction to Computing for Creative Practice | 10 |

| Core Courses | Units |
|--|-------|
| 05-391 Designing Human Centered Software (DHCS)1: This course provides an overview of the most important methods taught in the Additional Major in HCI, such as Contextual Inquiry, Prototyping and Iterative Design, Heuristic Evaluation, and Think Aloud User Studies. It covers in a more abbreviated form the content of 05-410 User-Centered Research and Evaluation and, 05-430 Programming Usable Interfaces. Alternatively, a student can take both 05-410 and 05-430 OR 05-380. If students take this course sequence, they get credit for fulfilling this 05-391 requirement plus one elective. | 12 |

| | |
|--|----|
| 05-360 Interaction Design Fundamentals | 12 |
|--|----|

Special Notes for Design Majors: HCI Minors who have a primary major in Design may substitute taking 05-391 Designing Human-Centered Software with another HCI 05 elective course; HCI Minors who have a primary major in Design must substitute taking 05-360 Interaction Design for Human Computer Interaction with another HCI 05-xxx course.

Electives

HCI minor students must take four HCI-related electives (9 units or more). Electives are intended to provide minor students with advanced concepts and skills relevant to HCI or breadth of experience not available from their primary major. Given these goals, most electives will be 300-level courses or higher. Courses at the 100-level and 200-level in one's primary major will not count as electives, although the same course taken by a non-major may count (approval is required).

Students can take electives in the HCII or courses relevant to HCI from many other departments on campus. All external electives are approved on a case-by-case basis.

All 05-xxx courses are pre-approved as HCI electives; however, core courses cannot double-count as electives. See the HCII website for a list of current pre-approved electives: <https://www.hcii.cmu.edu/academics/hci-undergrad/electives>

Double Counting

Students may double count up to two (2) of the required core and elective courses (prerequisite courses do not apply to the double-counting rule) with their primary major.

Relationship Between The HCI Additional Major and HCI Minor

Admission

- **HCI Additional Major:** Application and admissions required, information on the HCII website (<https://www.hcii.cmu.edu/academics/hci-undergrad/additional-major-hci/admissions/>).

- **HCI Minor:** Application and admissions required, information on the HCII website (<https://www.hcii.cmu.edu/academics/hci-undergrad/minor-hci/>).

Prerequisites (not necessary for admission)

- **HCI Additional Major:**
 - Freshman-level programming
 - Statistics
 - Psychology
 - Interaction Design for Human Computer Interaction
- **HCI Minor:**
 - Freshman-level programming

Core Courses

- **HCI Additional Major:**
 - Advanced Design Course
 - User Centered Research & Evaluation (UCRE)
 - Programming Usable Interfaces (PUI) or Prototyping Algorithmic Experiences (PAX) or Software Structures for User Interfaces (SSUI)
 - BHCI Project (Capstone)
- **HCI Minor:**
 - Interaction Design for Human-Computer Interaction
 - Designing Human-Centered Systems (DHCS)

Electives

- **HCI Additional Major:** Four (4) electives
- **HCI Minor:** Four (4) electives

Double Counting

- **HCI Additional Major:** Two (2) core courses or electives with primary major.
- **HCI Minor:** Two (2) core courses or electives with primary major.

Human-Computer Interaction Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units

This course is for HCII students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-120 Introduction to Human-Computer Interaction

Spring: 5 units

This course is only for freshman SCS students that are interested in learning more about HCI.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units

[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences through a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units

HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-315 Persuasive Design

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units

This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: <https://hcie.cmu.edu/academics/courses> (<https://hcie.cmu.edu/academics/courses/>)

05-318 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <http://www.hcie.cmu.edu/academics/courses> (<http://www.hcie.cmu.edu/academics/courses/>)

05-319 Data Visualization

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>

05-320 Social Web

Intermittent: 12 units

With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units

TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units

Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: <http://www.hcie.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci> (<http://www.hcie.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/>)

05-341 Organizational Communication

All Semesters: 9 units

Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: <http://www.hcie.cmu.edu/courses/organizational-communication> (<http://www.hcie.cmu.edu/courses/organizational-communication/>)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to: -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor. Prerequisites: 15-112 and (15-122 or 15-121 or 15-150 or 15-210) and (05-410 or 05-391) and (05-452 or 05-650 or 05-651 or 05-470 or 05-317)

05-391 Designing Human Centered Software

All Semesters: 12 units

"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite. " Prerequisites: 15-110 or 15-104 or 15-122 or 15-112

Course Website: <http://www.hcii.cmu.edu/courses/designing-human-centered-software/> (<http://www.hcii.cmu.edu/courses/designing-human-centered-software/>)

05-392 Interaction Design Overview

Fall: 9 units

This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required.

05-395 Applications of Cognitive Science

Spring: 9 units

The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: <http://www.hcii.cmu.edu/courses/applications-cognitive-science/> (<http://www.hcii.cmu.edu/courses/applications-cognitive-science/>)

05-410 User-Centered Research and Evaluation

Fall: 12 units

This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.

05-413 Human Factors

Fall: 9 units

This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: <http://www.hcii.cs.cmu.edu>

05-417 Computer-mediated Communication

Spring: 6 units

This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units

The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: <https://www.hcii.cmu.edu/course/design-of-educational-games> (<https://www.hcii.cmu.edu/course/design-of-educational-games/>)

05-430 Programming Usable Interfaces

Spring: 15 units

This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCI Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program. Prerequisites: 15-127 or 15-112 or 15-110 or 15-104 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units

This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCI programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work. Prerequisites: 17-514 or 17-437 or 17-214 or 14-513 or 15-513 or 18-213 or 15-213 or 15-214

05-432 Personalized Online Learning

Fall: 12 units

Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: <http://www.hcii.cmu.edu/courses/personalized-online-learning> (<http://www.hcii.cmu.edu/courses/personalized-online-learning/>)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units

Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCI Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units

Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCI graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCI undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: <http://www.hcii.cmu.edu/courses/applied-machine-learning> (<http://www.hcii.cmu.edu/courses/applied-machine-learning/>)

05-435 Applied Fabrication for HCI

Fall: 12 units

This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be \$400-\$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: <http://www.hcii.cmu.edu/courses/usable-privacy-and-security> (<http://www.hcii.cmu.edu/courses/usable-privacy-and-security/>)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <http://data.cmu.org>

05-440 Interaction Techniques

Intermittent: 12 units

This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: <http://www.cs.cmu.edu/~bam/uicourse/05440inter/>

05-452 Service Design

Fall: 12 units

In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-499 Special Topics in HCI

Fall and Spring: 12 units

Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: <http://www.hcii.cmu.edu/academics/courses> (<http://www.hcii.cmu.edu/academics/courses/>)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units

This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: <http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems> (<http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/>)

05-571 Undergraduate Project in HCI

Spring: 12 units

Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use. Prerequisites: 05-610 Min. grade B or 05-431 Min. grade B or 05-630 Min. grade B or 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B

Course Website: <http://www.hcii.cmu.edu/courses/undergraduate-project-hci> (<http://www.hcii.cmu.edu/courses/undergraduate-project-hci/>)

05-589 Independent Study in HCI-UG

All Semesters

In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units

This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component: To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component: To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: <http://www.hcii.cs.cmu.edu>**05-602 IDEATe: Learning in Museums**

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units

This course provides and overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.

Course Website: <http://www.hcii.cs.cmu.edu>**05-615 Persuasive Design**

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <https://www.hcii.cmu.edu/academics/courses> (<https://www.hcii.cmu.edu/academics/courses/>)**05-619 Data Visualization**

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>**05-650 Interaction Design Studio II**

Spring: 12 units

This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.

Prerequisite: 05-651

Course Website: <http://www.hcii.cmu.edu/courses/interaction-design-studio> (<http://www.hcii.cmu.edu/courses/interaction-design-studio/>)**05-651 Interaction Design Studio 1**

Fall: 12 units

This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. - Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-670 Digital Service Innovation

Fall: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters

With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with the permission of the instructor. Prerequisites: 15-112 and (15-121 or 15-150 or 15-210 or 15-122) and (05-891 or 05-610) and (05-651 or 05-650 or 05-652 or 05-617 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units

The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, high school, postsecondary, and adult education will be discussed and related to relevant state, national, and international standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, schools, and social systems. Assignments will emphasize linking goals - instruction - assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. Undergraduates are invited to take this course with special permission from Dr. Lauren Herckis.

05-823 E-Learning Design Principles and Methods

Fall: 12 units

This course is about e-learning design principles, the evidence and theory behind them, and how to apply these principles to develop effective educational technologies. It is organized around the book "e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning" by Clark and Mayer with further readings drawn from cognitive science, educational psychology, and human-computer interaction. You will learn design principles 1) for combining words, audio, and graphics in multimedia instruction, 2) for combining examples, explanations, practice and feedback in online support for learning by doing, and 3) for balancing learner versus system control and supporting student metacognition. You will read about the experiments that support these design principles, see examples of how to design such experiments, and practice applying the principles in educational technology development.

Course Website: http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013#Course_Details (http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013/#Course_Details)

05-839 Interactive Data Science

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-840 Tools for Online Learning

Fall: 12 units

In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

SCS Additional Minors

This page lists Additional Majors and Minors apart from those in Artificial Intelligence (p. 689), Computational Biology (p. 694), Computer Science (p. 698), Human-Computer Interaction (p. 703) and Robotics. Select from the tabs below to view more information about each program.

Students should consult with their own academic advisor as well as the advisor for the given minor for specific double-counting rules, especially for students who are pursuing an SCS minor with a major or other minors closely related to computing. Additional help can be provided by the Associate Dean in the Computer Science Undergraduate Program office (Gates-Hillman Center, 4th Floor).

A note on SCS Concentrations: Computer Science majors are required to pursue a minor outside of SCS or a concentration within SCS. Additional majors in SCS are still allowed for Computer Science majors. Artificial Intelligence, Computational Biology, Human-Computer Interaction and Robotics majors can complete an SCS concentration if they wish, but it is not required for these degrees. Minors in SCS will not be allowed for SCS students where there is an aligned concentration. For example, an SCS student cannot minor in Machine Learning since there is a Machine Learning concentration. Consult the SCS Concentrations section for details on available SCS concentrations.

IDEaTE Minors

Kelly Delaney, *Advisor*
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The Integrative Design, Arts and Technology (IDEaTE) network offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students engage in active "learning by doing" in state-of-the-art maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDEaTE undergraduate curriculum consists of ten areas, all of which can be taken as minors. The themes of these areas integrate knowledge in technology and the arts. Five of these minors are based in the School of Computer Science:

Animation & Special Effects Minor

Animation & Special Effects comprise a rich field of inquiry at the intersection of art, science, and technology. Students in the IDEaTE *Animation & Special Effects* minor will gain experience and competency across a wide range of techniques, while learning about the diverse histories, theories, and practices of animation from renowned faculty experts and visiting artists. Coursework cultivates development of unique aesthetics and individual voice through opportunities for group critique, iteration, public screening and exhibition. Through the minor, students will: have opportunities to collaborate and connect with peers in other fields of research; develop relevant practical skills and abilities that can be applied across a variety of independent studio and industry contexts; deepen cultural sensitivities while expanding their own creative practices; and develop a compelling animation portfolio. In particular, students will gain skills and competencies in the following areas:

- Storytelling through animation
- Digital 2D and 3D animation techniques
- Expanded and experimental animation methods
- Real-time animation systems
- Motion-capture technologies
- Visual effects and procedural animation
- Rendering and compositing

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDEaTE Portal Course - Minimum of 9 Units

| | | Units |
|--------|---|-------|
| 60-125 | IDEaTE: Introduction to 3D Animation Pipeline Recommended portal course for this area | 12 |
| 16-223 | IDEaTE Portal: Creative Kinetic Systems | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEaTE: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-223 | IDEaTE Portal: Introduction to Physical Computing | 10 |
| 62-150 | IDEaTE Portal: Introduction to Media Synthesis and Analysis | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
| 99-361 | IDEaTE Portal | 9 |

IDEaTE Animation & Special Effects Courses - Minimum of 27 Units

| | | Units |
|---------------|--|-------|
| 15-463 | Computational Photography | 12 |
| 15-465/60-414 | Animation Art and Technology | 12 |
| 53-320 | IDEaTE Special Topics in Animation: Character Modeling | 6 |
| 53-321 | IDEaTE Special Topics in Animation: Bipedal Rigging for Animation Production | 6 |
| 53-323 | IDEaTE Storytelling Through Effects Animation | 6 |
| 60-220 | IDEaTE: Technical Character Animation | 10 |
| 60-333 | IDEaTE: Animation Rigging | 10 |
| 60-335 | IDEaTE Special Topics in Animation: Story Development | 6 |
| 60-398 | Critical Studies: Social History of Animation | 9 |
| 60-413 | Advanced ETB: Real-Time Animation | 10 |
| 60-415 | Advanced ETB: Animation Studio | 10 |
| 60-417 | Advanced ETB: Video Art | 10 |

Additional course options as available. Please refer to the IDEaTE website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Animation & Special Effects* minor courses toward other requirements.

Intelligent Environments Minor

Students in the *Intelligent Environments* minor are concerned with the design and realization of interactive 3D spaces, both physical and virtual.

Students in this minor can explore how information and energy flow between physical, electronic, and computational spaces. By moving through space and time, we make sense of the world using our bodies. Just as we shape the environments around us, they in turn shape our experiences and senses, making us mindful of the need to develop responsible, equitable and inclusive environments. As a student in Intelligent Environments, through experimentation, hands-on learning, reflection, and documentation, you will learn:

- Analytical skills for the visualization and realization interactive spaces
- Principles of multimodal and embodied interactions

- 3-dimensional computer-aided design (CAD) for visualization, simulation, and fabrication
- The cultural context, and social and environmental implications of constructed environments

Students in this minor work in tandem with the Physical Computing and Media Design areas, which provide knowledge in key component elements of integrative intelligent environments. Accordingly, students can customize their studies by combining courses across these three concentrations with the help of their advisors.

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDEATe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 16-223 | IDEATe Portal: Creative Kinetic Systems Recommended Portal Course for this area | 10 |
| 60-223 | IDEATe Portal: Introduction to Physical Computing Recommended Portal Course for this area | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-125 | IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
| 99-361 | IDEATe Portal | 9 |

IDEATe Intelligent Environments Courses - Minimum of 27 Units

| | | Units |
|-----------|---|-------|
| 05-333 | Gadgets, Sensors and Activity Recognition in HCI | 12 |
| 16/54-375 | IDEATe: Robotics for Creative Practice | 10 |
| 16-376 | IDEATe: Kinetic Fabrics | 10 |
| 16-467 | Human Robot Interaction | 12 |
| 18/05-540 | Rapid Prototyping of Computer Systems | 12 |
| 48-528 | IDEATe: Responsive Mobile Environments | 9 |
| 51-361 | HyperSENSE: Augmenting Human Experience in Environments | 9 |
| 53-558 | Reality Computing Studio | 12 |
| 99-362 | IDEATe: Intelligent Learning Spaces | 9 |

Additional course options as available. Please refer to the IDEATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Intelligent Environments* minor courses toward other majors and minors.

Design for Learning Minor

Students in the *Design for Learning* minor, offered by the Human-Computer Interaction Institute (<http://coursecatalog.web.cmu.edu/schools-colleges/schoolofcomputerscience/addlmajorsminors/hcii.cmu.edu>) (HCI), combine skills to imagine, design, iterate, and evaluate effective new media systems for learning—from creating games for learning to integrating adaptive ed-tech and augmented reality experiences into diverse learning settings. In team-based collaborations, students focus on the critical design of learning platforms, products, and systems that leverage emerging technologies, learning science research, inclusive design, and data analytics to create engaging educational experiences with measurable real-world impact.

Through coursework in the minor, you will gain skills and competencies in:

- Learning design research and evaluation methods
- Concept modeling and prototyping techniques
- Learner-centered, inclusive and backward design frameworks
- Applied learning research and theory in team-based projects
- Communicating design choices and concepts to diverse stakeholders

Students in *Design for Learning* courses can bring media-making and prototyping competencies gained in other IDEATe areas (e.g. Game Design, Media Design, Physical Computing, Immersive Technologies in Arts & Humanities) to craft innovative learning experiences.

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDEATe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area | 10 |
| 99-361 | IDEATe Portal Recommended Portal Course for this area | 9 |
| 16-223 | IDEATe Portal: Creative Kinetic Systems | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-125 | IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 60-223 | IDEATe Portal: Introduction to Physical Computing | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |

IDEATe Design for Learning Courses - Minimum of 27 Units

| | | |
|--------|--|------|
| 05-291 | Learning Media Design | 12 |
| 05-292 | IDEATe: Learning in Museums | 12 |
| 05-321 | Transformational Game Design Studio | 12 |
| 05-418 | Design Educational Games | 12 |
| 05-432 | Personalized Online Learning | 12 |
| 05-738 | Evidence-Based Educational Design | 12 |
| 05-823 | E-Learning Design Principles and Methods | 12 |
| 51-486 | Designing Experiences for Learning | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 82-288 | Everyday Learning: Designing Learning Exp in Times of Unrest & Uncertainty | Var. |
| 90-463 | Policy and Leadership in Public Education | 6 |
| 99-362 | IDEATe: Intelligent Learning Spaces | 9 |

Additional course options as available. Please refer to the IDEATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Design for Learning* minor courses toward requirements for other majors and minors.

Physical Computing Minor

Physical computing is driven by a creative combination of arts and engineering disciplines. Our students' projects interact with their surroundings, remember information, make decisions, and generate tangible outputs like movement, sound, or light. Physical computing projects range from the tiny and plain (a blinking light on a breadboard) to the extravagant (a simulation of an alien landscape), and everything in between. They may be functional, like an assistive device for a person with disability, playful, like an interactive marble run, or exploratory, like a prototype for a future human-computer interface in a world of sentient machines.

Students gain a broad range of skills in our courses because physical computing as a field is fundamentally interdisciplinary: our projects combine software, electronics, and physical fabrication. Students in the *Physical Computing* minor learn how to:

- Write low-level software to computationally define a project's behavior, usually using C or Python
- Fabricate projects using techniques borrowed from various crafts and disciplines, such as making simple assemblies with paper and tape; woodworking for larger or more robust projects; textile/fabric integrations; and creating powered mechanical linkages using motors/gears/belts/bearings/etc.
- Design, test, assemble, and debug electronic circuits to bring a project to life
- Use 3-dimensional computer-aided design (CAD) for visualization, simulation, and fabrication of all of the above
- Combine digital fabrication techniques (3D printing, laser cutting, etc.) with hand craft to iterate towards creating a final, polished product

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDeATe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 16-223 | IDEATe Portal: Creative Kinetic Systems Recommended Portal Course for this area | 10 |
| 60-223 | IDEATe Portal: Introduction to Physical Computing Recommended Portal Course for this area | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-125 | IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
| 99-361 | IDEATe Portal | 9 |

IDEATe Physical Computing Courses - Minimum of 27 Units

| | | Units |
|-----------|--|-------|
| 05-333 | Gadgets, Sensors and Activity Recognition in HCI | 12 |
| 05/18-540 | Rapid Prototyping of Computer Systems | 12 |
| 15-294 | Special Topic: Rapid Prototyping Technologies | 5 |
| 15-394 | Intermediate Rapid Prototyping | 5 |
| 16/54-375 | IDEATe: Robotics for Creative Practice | 10 |
| 16-376 | IDEATe: Kinetic Fabrics | 10 |
| 16-480 | IDEATe: Special Topics: Creative Soft Robotics | 10 |
| 18/05-540 | Rapid Prototyping of Computer Systems | 12 |
| 18-578 | Mechatronic Design | 12 |
| 24-672 | Special Topics in DIY Design and Fabrication | 12 |
| 39-245 | Rapid Prototype Design | 9 |
| 48-528 | IDEATe: Responsive Mobile Environments | 9 |
| 62-362 | IDEATe: Electronic Logics && Creative Practice | 12 |
| 62-478 | IDEATe: digiTOOL | 9 |

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Physical Computing* minor courses toward requirements for other majors and minors.

Soft Technologies Minor

Soft technologies is an emerging field of robotics, the arts, craft, and engineering with far-reaching commercial, research, and social implications. Individual disciplines address components of this burgeoning field, but the IDeATe *Soft Technologies* minor helps students integrate the pieces to be able to make significant contributions to this developing sphere. Through the courses in the minor, students weave together a rich set of established and experimental techniques in traditional soft materials (such as fibers and textiles) and new soft materials (such as current hybrid and dynamic materials) to design and create a variety of forms with applications ranging from novel to practical. Students explore the unique qualities that soft material technologies afford in design and interaction in relationship to environments and the human body— responsiveness, adaptivity, flexibility, sensitivity, morphing, and biomimicry. Students will engage in project-based inquiry, using research, experimentation, making, and reflection to inform their creativity and to develop critical perspectives. Students will be able to envision their own projects and develop sensitivities to the breadth and limitations of soft technologies.

Through coursework in the minor, you will gain skills and competencies in:

- Manipulating traditional soft materials (such as fibers and textiles) and new soft materials (such as current hybrid and dynamic materials).
- Constructing 3-dimensional forms from 2-dimensional planes.
- Articulating material and conceptual choices in discussions and critiques.
- Analyzing the relationships between materials, form, use, and content integral to making.
- Researching and engaging with contemporary and/or historical precedents in the field

Curriculum

One Computing Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

One IDeATe Portal Course - Minimum of 9 Units

| | | Units |
|--------|--|-------|
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area | 10 |
| 99-361 | IDEATe Portal Recommended Portal Course for this area | 9 |
| 16-223 | IDEATe Portal: Creative Kinetic Systems | 10 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 | IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 60-125 | IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 60-223 | IDEATe Portal: Introduction to Physical Computing | 10 |
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |

IDEATe Soft Technologies Courses - Minimum of 27 Units

| | | Units |
|--------|---|-------|
| 09-227 | The Culture of Color: Dyes, Chemistry, and Sustainability | 9 |
| 15-367 | Algorithmic Textiles Design | 12 |
| 16-224 | IDEATe: Re-Crafting Computational Thinking with Soft Technologies | 6 |
| 16-376 | IDEATe: Kinetic Fabrics | 10 |
| 27-505 | Exploration of Everyday Materials | 9 |
| 54-346 | Introduction to Costume Construction | 6 |
| 54-486 | Understanding Textiles | 3 |

Additional course options as available. Please refer to the IDeATe website for courses for the current and upcoming semester.

Double-Counting

Students may double-count up to two of their *Soft Technologies* minor courses toward requirements for other majors and minors.

Information Security, Privacy, and Policy Minor

Lujo Bauer, Director

There is a growing demand for security and privacy experts, and increasing interest among CMU undergraduates in taking security and privacy courses. Security and privacy expertise is an asset in a variety of careers outside, not just in computer science, but also in areas that include business, management, and law. In addition, the policy side of security and privacy is becoming increasingly important and employers are interested in hiring people with an understanding of relevant policy issues, especially in the privacy and security area.

This minor is for undergraduate students across the university who are interested in policy issues related to security and privacy, including those who are planning careers in security/privacy as well as those who plan to focus their careers in other areas. The curriculum has been designed to accommodate students from any major as long as they have taken at least one introductory-level college programming course (such as 15-110 or 15-112).

After completing this minor, students will have a good understanding of how to identify potential security and privacy risks and relevant legal and policy issues; a working understanding of security topics such as cryptography, authentication, and Internet security protocols; as well as broad knowledge of several security- and privacy-related areas as they pertain to the design, development, deployment and management of technologies in a variety of practical contexts (e.g., Web, mobile, Internet of Things, social media, crypto currencies).

Admission

Students are not required to apply to enroll in this minor to start the required courses. However, students should declare their intent to complete the minor and submit a planned course of study to the minor director, and are encouraged to consult with the minor director on their elective course selection. In addition, students doing the independent study option must get approval from the minor director prior to enrolling in their independent study course. Finally, students must contact the minor director to certify their completion of the minor.

Curriculum

Students are required to take five courses to complete this minor with a minimum of 48 units.

INTRODUCTORY SECURITY COURSE

| | | |
|--------|---|----|
| 17-331 | Information Security, Privacy, and Policy | 12 |
|--------|---|----|

Students who have taken 15-213 Introduction to Computer Systems may substitute 15-330 Introduction to Computer Security/18-330 Introduction to Computer Security

PRIVACY AND POLICY COURSE

| | | |
|--------|-------------------------------------|---|
| 17-333 | Privacy Policy, Law, and Technology | 9 |
|--------|-------------------------------------|---|

Students may substitute 12-unit version of this course: 17-733, 19-608, or 95-818.

PRIVACY ELECTIVE

| Complete a minimum of 9 units: | | Units |
|--------------------------------|---|-------|
| 17-334 | Usable Privacy and Security (or 19-534 or 05-436) | 9 |
| 17-702 | Current Topics in Privacy Seminar (3-unit Mini) | 3 |
| 17-731 | Foundations of Privacy | 12 |
| 17-735 | Engineering Privacy in Software | 12 |
| 17-880 | Algorithms for Private Data Analysis | 12 |
| 94-806 | Privacy in the Digital Age | 6 |

Crosslisted courses are also allowed.

TECHNOLOGY AND POLICY ELECTIVE

| Complete a minimum of 9 units: | | Units |
|--------------------------------|---------------------------------------|-------|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 19-211 | Ethics and Policy Issues in Computing | 9 |

| | | |
|--------|---|----|
| 17-562 | Law of Computer Technology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-402 | Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 | Policies of Wireless Systems | 12 |
| 19-639 | Policies of the Internet | 12 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |

Crosslisted courses are also allowed.

ADDITIONAL APPROVED ELECTIVE

Students must complete an additional elective of 9 units or more. Students may choose an additional privacy elective or technology policy elective from the list above, or the one of the following security electives:

| | | |
|--------|--|------|
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-356 | Introduction to Cryptography | 12 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | Var. |
| 17-334 | Usable Privacy and Security | 9 |
| 18-335 | Secure Software Systems | 12 |
| 18-733 | Applied Cryptography | 12 |
| 18-435 | Foundations of Blockchains | 12 |
| 18-334 | Network Security | 12 |

Students who have the necessary prerequisites may choose any approved elective from the SCS or ECE security and privacy undergraduate concentration. Check with the minor program director to determine which category of elective each course will fulfill.

Students should be careful to choose electives for which they have appropriate prerequisites. New elective options are expected as more courses are offered. Students may petition to count a course not on this list as an elective. Students should request permission *before* taking a course that is not on this list. Students may not count multiple electives that overlap substantially.

Optional Project: Subject to approval by the minor director, students may optionally count towards one of the elective requirements 9 units of an independent study or research project course in the security or privacy area, under the supervision of a faculty member in any department.

In order to receive credit towards the minor, students must submit a brief project proposal to their project advisor and to the minor director and have it approved prior to conducting the project. Depending on the topic of the project, the minor director may approve credits counting towards privacy electives, technology policy electives, security electives, or some combination of these. Students may work individually, with other undergraduates, or as part of project teams with graduate students or research staff. Students involved in a group project must identify specific project components for which they are responsible. In addition, they must submit a final project report to their project advisor and the minor director that includes a literature review and describes the work they completed. Students working on a group project must each submit their own final report, which should also situate their contribution in the context of the larger project. Note, students are expected to work approximately 1 hour per week for each unit of project in which they are enrolled (e.g. 9 units = 9 hours/week of project work).

Double Counting: At most 2 of the courses used to fulfill the minor requirements may be counted towards any other undergraduate major or minor program. This rule does not apply to courses counted for general education requirements.

Language Technologies Minor

Carolyn P. Rose, *Chair*
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 www.lti.cs.cmu.edu/learn (http://www.lti.cs.cmu.edu/learn/)

Human language technologies have become an increasingly central component of computer science. Information retrieval, machine translation and speech technology are used daily by the general public, while text mining, natural language processing and language-based tutoring are common within more specialized professional or educational environments. The Language Technologies Institute prepares students for this world by offering a minor that gives you the opportunity to not only learn about language technologies, but to also apply that knowledge through a directed project.

Prerequisites

| Prerequisites | | Units |
|---------------|--------------------------------------|-------|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |

Recommended

| | | |
|-----------|--|----|
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 15-259 | Probability and Computing | 12 |
| or 21-325 | Probability | |
| or 36-218 | Probability Theory for Computer Scientists | |

Curriculum

Core requirement:

| | | |
|--------|--|----|
| 11-324 | Human Language for Artificial Intelligence | 12 |
|--------|--|----|

Electives (choose 3):

| | | |
|--------|---|----|
| 11-344 | Machine Learning in Practice | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Processing | 12 |
| 11-711 | Advanced Natural Language Processing | 12 |
| 11-731 | Machine Translation and Sequence-to-Sequence Models | 12 |
| 11-737 | Multilingual Natural Language Processing. | 12 |
| 11-747 | Neural Networks for NLP | 12 |
| 11-751 | Speech Recognition and Understanding | 12 |
| 11-752 | Speech II: Phonetics, Prosody, Perception and Synthesis | 12 |
| 11-761 | Language and Statistics | 12 |
| 11-776 | Multimodal Affective Computing | 12 |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |

Project:

| | |
|--|----|
| A semester-long directed research project OR paper to provide hands-on experience and an in-depth study of a topic (in same area as a chosen elective) | 12 |
|--|----|

Double Counting of Courses

Students may double count 11-324 Human Language for Artificial Intelligence and 80-180 Nature of Language toward any other major or minor.

Machine Learning Minor

Dr. Matt Gormley, *Program Director*

Laura Winter, *Program Coordinator*

ml-minor@cs.cmu.edu

www.ml.cmu.edu/academics/minor-in-machine-learning.html ([http://](http://www.ml.cmu.edu/academics/minor-in-machine-learning.html)

www.ml.cmu.edu/academics/minor-in-machine-learning.html)

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Minor in Machine Learning allows undergraduates to learn about the core principles of this field.

Prerequisites

The 3 prerequisite courses must be taken before a student applies to the Machine Learning Minor.

| Prerequisites | | Units |
|---------------|---|-------|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| or 21-127 | Concepts of Mathematics | |
| or 21-128 | Mathematical Concepts and Proofs | |
| 36-235 | Probability and Statistical Inference I | 9 |
| or 36-218 | Probability Theory for Computer Scientists | |
| or 36-219 | Probability Theory and Random Processes | |
| or 36-225 | Introduction to Probability Theory | |

or 15-259 Probability and Computing

or 21-325 Probability

Core Courses

The Machine Learning Minor has 2 core courses that provide a foundation in the field.

Core Courses

| | | |
|-----------|--|----|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| or 10-405 | Machine Learning with Large Datasets (Undergraduate) | |
| or 10-417 | Intermediate Deep Learning | |
| or 10-418 | Machine Learning for Structured Data | |

Electives

The Machine Learning Minor requires at least 3 electives of at least 9 units each in Machine Learning. Students may select one of the following options to satisfy the electives requirement:

- 3 Principal courses
- 2 Principal courses + 1 Interdisciplinary course
- 2 Principal courses + 1 semester of CS Senior Honors Thesis or Senior Research
- 1 Principal course + 2 semesters of CS Senior Honors Thesis or Senior Research

Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling.

Graduate-level cross-listings of these courses can also be used for the ML Minor, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.

Principal Electives

| | | |
|---------------------------|--|----|
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| or 10-703 | Deep Reinforcement Learning & Control | |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| or 10-605 | Machine Learning with Large Datasets | |
| or 10-745 | Scalability in Machine Learning | |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| or 11-485 | Introduction to Deep Learning | |
| or 10-707 | Advanced Deep Learning | |
| 10-418 | Machine Learning for Structured Data | 12 |
| or 10-708 | Probabilistic Graphical Models | |
| 10-425 | Introduction to Convex Optimization | 12 |
| or 10-725 | Convex Optimization | |
| 10-613 | Machine Learning Ethics and Society | 12 |
| 10-777 | Historical Advances in Machine Learning | 12 |
| 36-401 | Modern Regression | 9 |
| Other courses as approved | | |

Note: Courses must come from separate lines. For example, if 10-417 Intermediate Deep Learning is used for the ML Minor, 11-485 Introduction to Deep Learning cannot also be used for the ML Minor.

Interdisciplinary Electives

| | | |
|--------|---|------|
| 02-510 | Computational Genomics | 12 |
| 03-511 | Computational Molecular Biology and Genomics | 9 |
| 10-335 | Art and Machine Learning | 12 |
| 10-737 | Creative AI | Var. |
| 11-411 | Natural Language Processing | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-661 | Language and Statistics | 12 |
| 11-731 | Machine Translation and Sequence-to-Sequence Models | 12 |
| 11-751 | Speech Recognition and Understanding | 12 |
| 11-755 | Machine Learning for Signal Processing | 12 |
| 11-777 | Multimodal Machine Learning | 12 |

| | | |
|---------------------------|---|----|
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 15-388 | Practical Data Science | 9 |
| 15-482 | Autonomous Agents | 12 |
| 16-311 | Introduction to Robotics | 12 |
| 16-385 | Computer Vision | 12 |
| 16-720 | Computer Vision | 12 |
| 16-745 | Optimal Control and Reinforcement Learning | 12 |
| 16-824 | Visual Learning and Recognition | 12 |
| 16-831 | Introduction to Robot Learning | 12 |
| 17-537 | Artificial Intelligence Methods for Social Good | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-700 | Probability and Mathematical Statistics | 12 |
| Other courses as approved | | |

SCS Senior Honors Thesis

The SCS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 24 units (12 units each semester) may be counted towards the ML Minor. Students must consult with the Computer Science Department for information about the SCS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

07-599 SCS Honors Undergraduate Research Thesis Var.

Senior Research

Senior research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units and counting as 2 electives.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core or Affiliated Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Some samples of available Machine Learning Senior Projects are available on the Machine Learning Department webpage.

Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Minor Director to confirm that the project will count for the Machine Learning Minor.

The student should expect to meet with the Minor Director during both Senior Fall and Spring to discuss the project, and will present the work and submit a year-end write-up to the Minor Director at the end of Senior year.

10-500 Senior Research Project 24

Double Counting

No course in the Machine Learning Minor may be counted towards another SCS minor. Additionally, at least 3 courses (each being at least 9 units) must be used for only the Machine Learning Minor, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Minor.)

GRADES

All courses for the Machine Learning Minor, including prerequisites, must be passed with a C or better.

ADMISSION

The Machine Learning Minor is open to undergraduate students in any major at Carnegie Mellon outside the School of Computer Science. (SCS students should instead consider the Machine Learning Concentration.) Students should apply for admission at least one semester before their expected graduation date, but are encouraged to apply as soon as they have taken the prerequisite classes for the minor. The application can be found on the Machine Learning Minor website.

Neural Computation Minor

Dr. Tai Sing Lee, *Director*
Melissa Stupka, *Administrative Coordinator*

<https://www.cmu.edu/ni/academics/minor-in-neural-computation.html>

Neural computation is a scientific enterprise to understand the neural basis of intelligent behaviors from a computational perspective. Study of neural computation includes, among others, decoding neural activities using statistical and machine learning techniques, and developing computational theories and neural models of perception, cognition, motor control, decision-making and learning. The neural computation minor allows students to learn about the brain from multiple perspectives, and to acquire the necessary background for graduate study in neural computation. Students enrolled in the minor will be exposed to, and hopefully participate in, the research effort in neural computation and computational neuroscience at Carnegie Mellon University.

The minor in Neural Computation is an intercollege minor jointly sponsored by the School of Computer Science, the Mellon College of Science, and the Dietrich College of Humanities and Social Sciences, and is coordinated by the Neuroscience Institute (<https://www.cmu.edu/ni/>) and the Center for the Neural Basis of Cognition (CNBC) (<http://www.cnbc.cmu.edu/>).

The Neural computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, H&SS and MCS.

The Neural Computation minor is open to students in any major of any college at Carnegie Mellon. It seeks to attract undergraduate students from computer science, psychology, engineering, biology, statistics, physics, and mathematics from SCS, CIT, Dietrich College and MCS. The primary objective of the minor is to encourage students in biology and psychology to take computer science, engineering and mathematics courses, to encourage students in computer science, engineering, statistics and physics to take courses in neuroscience and psychology, and to bring students from different disciplines together to form a community. The curriculum and course requirements are designed to maximize the participation of students from diverse academic disciplines. The program seeks to produce students with both basic computational skills and knowledge in cognitive science and neuroscience that are central to computational neuroscience.

APPLICATION

Students must apply for admission no later than November 30 of their senior years; an admission decision will usually be made within one month. Students are encouraged to apply as early as possible in their undergraduate careers so that the director of the Neural Computation minor can provide advice on their curriculum, but should contact the program director any time even after the deadline.

To apply, send email to the director of the Neural Computation minor Dr. Tai Sing Lee (tai@cnbc.cmu.edu) and copy Melissa Stupka (mstupka@andrew.cmu.edu). Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Your class and College/School at Carnegie Mellon
- Semester you intend to graduate
- All (currently) declared majors and minors
- Statement of purpose (maximum 1 page) – Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses for the Minor (this is your plan, NOT a commitment)
- Research projects you might be interested in

Curriculum

The Minor in Neural Computation will require a total of five courses: four courses drawn from the four core areas (A: neural computation, B: neuroscience, C: cognitive psychology, D: intelligent system analysis), one from each area, and one additional depth elective chosen from one of the core areas that is outside the student's major. The depth elective can be replaced by a one-year research project in computational neuroscience. No more than two courses can be double counted toward the student's major or other minors. However, courses taken for general education requirements of the student's degree are not considered to be double counted. A course taken to satisfy one core area cannot be used to satisfy the course requirement for another core area. The following listing presents a set of current possible courses in each area. Other computational neuroscience courses are being developed at Carnegie Mellon and University of Pittsburgh that will also satisfy core area A requirement and the requirements will be updated as they come on-line. Substitution is possible but requires approval.

A. Neural Computation

15-386 Neural Computation

Units

9

| | | |
|---------------------------------------|--|----|
| 15-387 | Computational Perception | 9 |
| 15-883 | Computational Models of Neural Systems | 12 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 86-375 | Computational Perception | 9 |
| Pitt-Mathematics-1800 | Introduction to Mathematical Neuroscience | 9 |
| B. Neuroscience | | |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 03-365 | Neural Correlates of Learning and Memory | 9 |
| 42-630 | Introduction to Neural Engineering (crosslisted with 18-690) | 12 |
| 85-765 | Cognitive Neuroscience | 9 |
| Pitt-Neuroscience 1000 | Introduction to Neuroscience | 9 |
| C. Cognitive Psychology | | |
| 85-211 | Cognitive Psychology | 9 |
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-426 | Learning in Humans and Machines | 9 |
| 85-765 | Cognitive Neuroscience | 9 |
| D. Intelligent System Analysis | | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| or 10-315 | Introduction to Machine Learning (SCS Majors) | |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |
| 15-387 | Computational Perception | 9 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-299 | Introduction to Feedback Control Systems | 12 |
| 16-311 | Introduction to Robotics | 12 |
| 16-385 | Computer Vision | 12 |
| 18-290 | Signals and Systems | 12 |
| 24-352 | Dynamic Systems and Controls | 12 |
| 36-225 | Introduction to Probability Theory | 9 |
| 36-247 | Statistics for Lab Sciences | 9 |
| 36-401 | Modern Regression | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 42-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |
| 86-375 | Computational Perception | 9 |
| 86-631 | Neural Data Analysis | 12 |

Prerequisites

The required courses in the above four core areas require a number of basic prerequisites: basic programming skills at the level of 15-110 Principles of Computing and basic mathematical skills at the level of 21-122 Integration and Approximation or their equivalents. Some courses in Area D require additional prerequisites. Area B Biology courses require, at minimum, 03-121 Modern Biology. Students might skip the prerequisites if they have the permission of the instructor to take the required courses. Prerequisite courses are typically taken to satisfy the students' major or other requirements. In the event that these basic skill courses are not part of the prerequisite or required courses of a student's major, one of them can potentially count toward the five required courses (e.g. the depth elective), conditional on approval by the director of the minor program.

Research Requirements (Optional)

The minor itself does not require a research project. The student however may replace the depth elective with a year-long research project. In special circumstances, a research project can also be used to replace one of the five courses, as long as (1) the project is not required by the student's major or other minor, (2) the student has taken a course in each of the four core areas (not necessarily for the purpose of satisfying this minor's requirements), and (3) has taken at least three courses in this curriculum not counted toward the student's major or other minors. Students interested in participating in the research project should contact any faculty engaged in computational neuroscience or neural computation research at Carnegie Mellon or in the University of Pittsburgh. A useful webpage that provides listing of faculty in neural computation is <https://www.cmu.edu/ni/academics/pnc/pnc-training-faculty.html>.

The director of the minor program will be happy to discuss with students about their research interest and direct them to the appropriate faculty.

Fellowship Opportunities

The Program in Neural Computation (PNC) administered by the Center for the Neural Basis of Cognition currently provides 3-4 competitive full-year fellowships (\$11,000) to Carnegie Mellon undergraduate students to carry out mentored research in neural computation. The fellowship has course requirements similar to the requirements of the minor. Students do not apply to the fellowship program directly. They have to be nominated by the faculty members who are willing to mentor them. Therefore, students interested in the full-year fellowship program should contact and discuss research opportunities with any CNBC faculty at Carnegie Mellon or University of Pittsburgh working in the area of neural computation or computational neuroscience and ask for their nomination by sending email to Dr. Tai Sing Lee, who also administers the undergraduate fellowship program at Carnegie Mellon. See www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/ (<http://www.cnbc.cmu.edu/training/undergraduate/undergraduate-research-fellowships-in-computational-neuroscience/>) for details.

The Program in Neural Computation also offers a summer training program for undergraduate students from any U.S. undergraduate college. The students will engage in a 10-week intense mentored research and attend a series of lectures in neural computation. See www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/ (<http://www.cnbc.cmu.edu/training/undergraduate/summer-undergraduate-research-program-in-computational-neuroscience/>) for application information.

Software Engineering Minor

Michael Hilton, *Director*
mhilton@andrew.cmu.edu
<http://isri.cmu.edu/education/undergrad> (<http://isri.cmu.edu/education/undergrad/>)

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

The software engineering minor is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Admission

The Software Engineering Minor is open to undergraduate students in any major in the university. We encourage students to submit applications no later than 3 days before the beginning of Spring and Fall course registration, so that subsequent decisions can help students plan their subsequent course schedule effectively. However, students may petition the Director for admission outside this general schedule.

To apply, send the director an email. Include in your email:

- Full name
- Andrew ID
- Preferred email address (if different)
- Semester you intend to graduate
- QPA
- All (currently) declared majors and minors, or home college if no major declared
- Statement of purpose (maximum 1 page) - Describes why you want to take this minor and how it fits into your career goals
- Proposed schedule of required courses and internship (this is your plan, NOT a commitment)

Prerequisite

| | | |
|--------|---|----|
| 17-214 | Principles of Software Construction: Objects, Design, and Concurrency | 12 |
|--------|---|----|

Core Course Requirements

Complete both of the following courses.

| | | |
|--------|-------------------------------------|----|
| 17-313 | Foundations of Software Engineering | 12 |
| 17-413 | Software Engineering Practicum | 12 |

Electives

The minor requires three elective courses, one selected from each of the following categories:

1. One domain-independent course focused on technical software engineering material (min. 9 units):

Must complete at least 9 units, may comprise one 9-12 unit course or multiple minis

| | | |
|--------|--|----|
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-414 | Bug Catching: Automated Program Verification | 9 |
| 17-355 | Program Analysis | 12 |
| 17-356 | Software Engineering for Startups | 12 |
| 17-314 | Formal Methods *Mini: pair with 17-324 | 6 |
| 17-324 | Advanced Formal Methods * | 6 |
| 17-612 | Business and Marketing Strategy **Mini: pair with either 17-626 or 17-627 | 6 |
| 17-626 | Requirements for Information Systems ** | 6 |
| 17-627 | Requirements for Embedded Systems ** | 6 |
| 17-322 | Agile Methods ***Mini: pair with 17-332 and/or 17-442 | 6 |
| 17-332 | Software Project Management *** | 6 |
| 17-442 | Software Management Theory *** | 6 |
| 17-323 | Quality Assurance ****Mini: pair with 17-443 | 6 |
| 17-443 | Quality Management **** | 6 |
| 17-335 | Software Architectures Mini: add to other mini pairings as needed. | 6 |
| 17-731 | Foundations of Privacy | 12 |
| 17-821 | Computer Simulation of Complex Socio-Technical Systems | 12 |

Crosslisted courses allowed.

Other courses may be allowed, with prior approval from the Director of the Software Engineering Program.

2. One engineering-focused course with a significant software component (min. 9 units):

At least 9 units of the following:

| | | |
|--------|--|------|
| 15-410 | Operating System Design and Implementation | 15 |
| 15-412 | Operating System Practicum | Var. |
| 15-440 | Distributed Systems | 12 |
| 15-441 | Networking and the Internet | 12 |
| 15-445 | Database Systems | 12 |
| 17-437 | Web Application Development | 12 |
| 67-443 | Mobile Application Design and Development | 12 |

Crosslisted courses allowed

Other courses may be allowed, with prior approval from the Director of the Software Engineering Program.

3. One course that explores computer science problems in society and industry, related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts (min. 9 units):

At least 9 units of the following:

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |

| | | |
|--------|----------------------------------|----|
| 17-334 | Usable Privacy and Security | 9 |
| 17-562 | Law of Computer Technology | 9 |
| 19-403 | Policies of Wireless Systems | 12 |
| 70-311 | Organizational Behavior | 9 |
| 70-415 | Introduction to Entrepreneurship | 9 |
| 70-471 | Supply Chain Management | 9 |

Crosslisted courses allowed.**Required Internship and Reflection Course**

A software engineering internship of a minimum of 8 full-time weeks in an industrial setting is required. The student must be integrated into a team and exposed to industry pressures. The intern may work in development, management, quality assurance, or other relevant positions. The director of the SE minor program has sole discretion in approving an internship experience based on these criteria. Students should confirm that an internship position is appropriate before accepting it, but internships that fulfill the criteria will also be accepted after the fact.

- 17-415 *Software Engineering Reflection (required 6 unit course, number to be determined, to be offered Fall semester):* Each student will conduct an analysis of some personal software engineering experience, typically (but not always) based on the engineering internship above. The student will then write and edit a short paper presenting this analysis. Initial course meetings will cover the reflective, writing, and speaking process. In later meetings, each student will present his or her experience through a 30-45 minute talk, which will be evaluated for communication skills and critical reflective content. This course is limited to enrollment of 16, and students who are admitted to the minor program are given first priority.

Double Counting Rule

At most 2 of the courses used to fulfill the minor requirements may be counted towards any other major or minor program. This rule does not apply to 17-214 (a prerequisite for the minor) or courses counted for general education requirements, nor does it apply to double-counting with the SCS General Education requirements.

Other Departments and Institutes Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

Computational Biology Courses

02-201 Programming for Scientists

Fall and Spring: 10 units

Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-218 Introduction to Computational Medicine

All Semesters: 3 units

This course is an introduction to computational methods relevant to the diagnosis and treatment of human diseases. It is the microcourse version of 02-518, Computational Medicine. The course begins with an introduction to the field of Medicine, and an overview of the primary clinical tasks associated with Computational Medicine (phenotyping; biomarker discovery; predictive modeling). Next, we provide an introduction to several Machine Learning techniques, and how those techniques can be used to perform the clinical tasks. For the remainder of the course, students will be guided through the analysis of a clinical data set to gain experience with these techniques. No prior experience with Medicine, Machine Learning, or computer programming is required. Students will be graded based on quizzes and one homework.

02-223 Personalized Medicine: Understanding Your Own Genome

Fall: 9 units

Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology

Spring: 12 units

This class provides a general introduction to computational tools for biology. The course is divided into two halves. The first half covers computational molecular biology and genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. The second half covers computational cell biology, including biological modeling and image analysis. It includes homework requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, and neuron behavior. The imaging component includes the basics of machine vision, morphological image analysis, image classification and image-derived models. The course is taught under two different numbers. The lectures are the same for both but recitations and examinations are separate. 02-250 is intended primarily for computational biology, computer science, statistics or engineering majors at the undergraduate or graduate level who have had prior experience with computer science or programming. 03-250 is intended primarily for biological sciences or biomedical engineering majors who have had limited prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit. Prerequisite: (02-201 or 15-110 or 15-112), or permission of the instructors. Prerequisites: (02-201 or 15-110 or 15-112) and (03-151 or 03-131 or 03-121)

Course Website: <http://www.cbd.cmu.edu/education/undergraduate-courses/introduction-to-computational-biology/>

02-251 Great Ideas in Computational Biology

Spring: 12 units

This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded 6students who are interested in exploring the field. Students will learn fundamental algorithmic and machine learning techniques that are used in modern biological investigations, including algorithms to process string, graph, and image data. They will use these techniques to answer questions such as "How do we reconstruct the sequence of a genome?", "How do we infer evolutionary relationships among many species?", and "How can we predict each gene's biological role?" on biological data. Previous exposure to molecular biology is not required, as the instructors will provide introductory materials as needed. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology. Prerequisites: (15-112 or 02-201) and (15-151 or 21-127 or 21-128)

02-261 Quantitative Cell and Molecular Biology Laboratory

Fall and Spring

This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.

Prerequisites: 15-112 or 02-201

02-262 Computation and Biology Integrated Research Lab

All Semesters

Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both. Pre-requisites include either (03-117 or 03-124 or 03-343) or (15-112 or equivalent)

02-317 Algorithms in Nature

Intermittent: 9 units

Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.

Prerequisites: 15-210 and 15-251

Course Website: <http://www.algorithmsinnature.org>**02-319 Genomics and Epigenetics of the Brain**

Fall: 9 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.

Prerequisites: (03-121 or 03-151) and (03-220 or 03-221) and (15-121 or 15-112 or 15-110 or 02-201)

02-331 Modeling Evolution

Spring: 12 units

Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.

Prerequisites: 15-112 and 21-241 and (36-218 or 21-325 or 36-225 or 15-259)

02-402 Computational Biology Seminar

Fall and Spring: 3 units

This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80% of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

02-403 Special Topics in Bioinformatics and Computational Biology

Intermittent: 6 units

A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use ²H, ¹³C or ¹⁵N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

Prerequisites: (02-250 Min. grade C or 03-250 Min. grade C) and 03-121 Min. grade C

02-414 String Algorithms

Intermittent: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.

Prerequisites: 21-128 or 15-151 or 15-127

02-421 Algorithms for Computational Structural Biology

Intermittent: 12 units

Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics

Spring: 9 units

Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.

Prerequisites: 02-250 or 02-604 or 02-251

02-450 Automation of Scientific Research

Spring: 9 units

Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.

Prerequisites: (10-701 or 10-315) and 15-122

02-499 Independent Study in Computational Biology

Fall and Spring

The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology

Fall and Spring

This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

Course Website: <https://forms.gle/S1AJX65btkTxwNCw9> (<https://forms.gle/S1AJX65btkTxwNCw9/>)**02-510 Computational Genomics**

Spring: 12 units

Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

Prerequisites: 15-122 Min. grade C and (15-259 or 36-225 or 36-218 or 36-325)

02-512 Computational Methods for Biological Modeling and Simulation

Fall: 9 units

This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.

Prerequisites: 15-112 or 02-201 or 15-110

02-514 String Algorithms

Fall: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.

Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics

Spring: 12 units

Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for critiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine

Fall: 12 units

Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: <https://sites.google.com/view/computationalmedicine/>

02-530 Cell and Systems Modeling

Fall: 12 units

This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. Prerequisites: (03-121 or 33-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

02-540 Bioimage Informatics

Intermittent: 12 units

With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

Prerequisites: 02-620 or 10-301 or 10-315 or 10-601 or 10-701

02-601 Programming for Scientists

Fall and Spring: 12 units

Provides a practical introduction to programming for students with little previous programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments may be given in other programming languages to highlight the commonalities and differences between languages. No biology background is needed. Analytical skills, an understanding of programming basics, and mathematical maturity are required.

Course Website: <http://compeau.cbd.cmu.edu/programming-for-scientists/>**02-602 Professional Issues for Computational and Automated Scientists**

Fall and Spring: 3 units

This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics

Spring: 12 units

How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601.

02-605 Professional Issues in Automated Science

Spring: 3 units

This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures

Fall and Spring: 12 units

The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested prerequisite for undergraduates.

02-614 String Algorithms

Intermittent: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.

Prerequisites: 15-151 or 15-127 or 21-128

02-620 Machine Learning for Scientists

Spring: 12 units

With advances in scientific instruments and high-throughput technology, scientific discoveries are increasingly made from analyzing large-scale data generated from experiments or collected from observational studies. Machine learning methods that have been widely used to extract complex patterns from large speech, text, and image data are now being routinely applied to answer scientific questions in biology, bioengineering, and medicine. This course is intended for graduate students interested in learning machine learning methods for scientific data analysis and modeling. It will cover classification and regression techniques such as logistic regression, random forest regression, Gaussian process regression, decision trees, and support vector machines; unsupervised learning methods such as clustering algorithms, mixture models, and hidden Markov models; probabilistic graphical models and deep learning methods; and learning theories such as PAC learning and VC dimension. The course will focus on applications of these methods in genomics and medicine. Programming skills and basic knowledge of linear algebra, probability, statistics are assumed.

Prerequisite: 02-680

02-651 New Technologies and Future Markets

Fall: 12 units

This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understand the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.

Prerequisite: 11-695

02-654 Biotechnology Enterprise Development

Fall: 12 units

In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understand customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essential elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.

Prerequisites: 11-695 and 02-651

02-680 Essential Mathematics and Statistics for Scientists

Fall: 9 units

This course rigorously introduces fundamental topics in mathematics and statistics to first-year master's students as preparation for more advanced computational coursework. Topics are sampled from information theory, graph theory, proof techniques, phylogenetics, combinatorics, set theory, linear algebra, neural networks, probability distributions and densities, multivariate probability distributions, maximum likelihood estimation, statistical inference, hypothesis testing, Bayesian inference, and stochastic processes. Students completing this course will obtain a broad skillset of mathematical techniques and statistical inference as well as a deep understanding of mathematical proof. They will have the quantitative foundation to immediately step into an introductory master's level machine learning or automation course. This background will also serve students well in advanced courses that apply concepts in machine learning to scientific datasets, such as 02-710 (Computational Genomics) or 02-750 (Automation of Biological Research). The course grade will be computed as the result of homework assignments, midterm tests, and class participation.

02-699 Independent Study in Computational Biology

Fall and Spring

The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-700 M.S. Thesis Research

Fall and Spring

This course is for M.S. students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator, who will enroll you in the course.

Course Website: <https://forms.gle/tDKDs1EujvXAApYK7> (<https://forms.gle/tDKDs1EujvXAApYK7/>)

02-702 Computational Biology Seminar

Fall and Spring: 3 units

This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80 percent of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

Course Website: <https://www.compbio.cmu.edu/seminar-series/index.html> (<https://www.compbio.cmu.edu/seminar-series/>)

02-703 Special Topics in Bioinformatics and Computational Biology

Intermittent: 6 units

A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use 2H, 13C or 15N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

02-710 Computational Genomics

Spring: 12 units

Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

02-711 Computational Molecular Biology and Genomics

Spring: 12 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam. Prerequisites: (03-151 or 03-121) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation

Fall: 12 units

This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.

Prerequisites: (15-110 or 15-112) and (02-201 or 02-613)

02-714 String Algorithms

Fall: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.

Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics

Spring: 12 units

Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for critiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature

Fall: 12 units

Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine

Fall: 12 units

Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite. Prerequisites: 10-315 or (10-701 and 10-601 and 10-401)

Course Website: <https://sites.google.com/view/computationalmedicine/>**02-719 Genomics and Epigenetics of the Brain**

Fall: 12 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology. Prerequisites: (03-151 or 03-121) and 03-220 and (02-201 or 15-110 or 15-121)

02-721 Algorithms for Computational Structural Biology

Intermittent: 12 units

Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics

Spring: 12 units

Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics. Prerequisites: 02-250 or 02-251 or 02-604

02-730 Cell and Systems Modeling

Fall: 12 units

This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT

Prerequisites: (33-121 or 03-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

Course Website: <https://sites.google.com/site/cellandsystemsmodeling/>

02-731 Modeling Evolution

Spring: 12 units

Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.

Prerequisites: 15-112 and 21-241 and (21-325 or 36-218 or 15-259 or 36-225)

02-740 Bioimage Informatics

Intermittent: 12 units

With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research

Spring: 12 units

Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.

Prerequisites: 10-601 or 10-701 or 02-620

02-760 Laboratory Methods for Computational Biologists

Fall and Spring: 9 units

Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I

Fall: 12 units

In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-762 Laboratory Methods for Automated Biology II

Spring: 12 units

This laboratory course provides a continuation and extension of experiences in 02-761. Instruction will consist of lectures and laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on the execution of a molecular biology experiment requiring nucleic acid extraction, library preparation for sequencing, and quality control. The second project will be focused on the implementation and execution of automated methods using active learning techniques to direct the learning of a predictive model for a large experimental space (such as learning the effects of many possible drugs on many possible targets). Grading will be based on lab and project completion and quality.

Prerequisite: 02-761

02-764 Automated Science Capstone II

Spring: 12 units

This course consists of small group projects on development, implementation and/or execution of automated science campaigns in collaboration with industry and/or academic partners. This course may only be taken as part of a continuous sequence with 02-763. Enrollment is only open to M.S. in Automated Science students.

Human-Computer Interaction Courses

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units

This course is for HCII students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-120 Introduction to Human-Computer Interaction

Spring: 5 units

This course is only for freshman SCS students that are interested in learning more about HCI.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units

[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences through a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units

HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-315 Persuasive Design

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units

This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-318 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <http://www.hcii.cmu.edu/academics/courses> (<http://www.hcii.cmu.edu/academics/courses/>)

05-319 Data Visualization

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>

05-320 Social Web

Intermittent: 12 units

With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units

TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units

Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: <http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci> (<http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/>)

05-341 Organizational Communication

All Semesters: 9 units

Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: <http://www.hcii.cmu.edu/courses/organizational-communication> (<http://www.hcii.cmu.edu/courses/organizational-communication/>)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to: -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor. Prerequisites: 15-112 and (15-122 or 15-121 or 15-150 or 15-210) and (05-410 or 05-391) and (05-452 or 05-650 or 05-651 or 05-470 or 05-317)

05-391 Designing Human Centered Software

All Semesters: 12 units

"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite." Prerequisites: 15-110 or 15-104 or 15-122 or 15-112

Course Website: <http://www.hcii.cmu.edu/courses/designing-human-centered-software> (<http://www.hcii.cmu.edu/courses/designing-human-centered-software/>)

05-392 Interaction Design Overview

Fall: 9 units

This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required.

05-395 Applications of Cognitive Science

Spring: 9 units

The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: <http://www.hcii.cmu.edu/courses/applications-cognitive-science> (<http://www.hcii.cmu.edu/courses/applications-cognitive-science/>)

05-410 User-Centered Research and Evaluation

Fall: 12 units

This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc. In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.

05-413 Human Factors

Fall: 9 units

This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: <http://www.hcii.cs.cmu.edu>

05-417 Computer-mediated Communication

Spring: 6 units

This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units

The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: <https://www.hcii.cmu.edu/course/design-of-educational-games> (<https://www.hcii.cmu.edu/course/design-of-educational-games/>)

05-430 Programming Usable Interfaces

Spring: 15 units

This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program. Prerequisites: 15-127 or 15-112 or 15-110 or 15-104 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units

This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCII programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work.

Prerequisites: 17-514 or 17-437 or 17-214 or 14-513 or 15-513 or 18-213 or 15-213 or 15-214

05-432 Personalized Online Learning

Fall: 12 units

Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: <http://www.hcii.cmu.edu/courses/personalized-online-learning> (<http://www.hcii.cmu.edu/courses/personalized-online-learning/>)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units

Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units

Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: <http://www.hcii.cmu.edu/courses/applied-machine-learning> (<http://www.hcii.cmu.edu/courses/applied-machine-learning/>)

05-435 Applied Fabrication for HCI

Fall: 12 units

This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be \$400-\$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: <http://www.hcii.cmu.edu/courses/usuable-privacy-and-security> (<http://www.hcii.cmu.edu/courses/usuable-privacy-and-security/>)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <http://data.cmu.org>

05-440 Interaction Techniques

Intermittent: 12 units

This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: <http://www.cs.cmu.edu/~bam/uicourse/05440inter/>

05-452 Service Design

Fall: 12 units

In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-499 Special Topics in HCI

Fall and Spring: 12 units

Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: <http://www.hcii.cmu.edu/academics/courses> (<http://www.hcii.cmu.edu/academics/courses/>)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units

This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: <http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems> (<http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/>)

05-571 Undergraduate Project in HCI

Spring: 12 units

Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-610 Min. grade B or 05-431 Min. grade B or 05-630 Min. grade B or 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B

Course Website: <http://www.hcii.cmu.edu/courses/undergraduate-project-hci> (<http://www.hcii.cmu.edu/courses/undergraduate-project-hci/>)

05-589 Independent Study in HCI-UG

All Semesters

In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units

This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component: To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component: To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: <http://www.hcii.cs.cmu.edu>

05-602 IDEATe: Learning in Museums

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units

This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.

Course Website: <http://www.hcii.cs.cmu.edu>

05-615 Persuasive Design

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <https://www.hcii.cmu.edu/academics/courses> (<https://www.hcii.cmu.edu/academics/courses/>)

05-619 Data Visualization

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>

05-650 Interaction Design Studio II

Spring: 12 units

This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.

Prerequisite: 05-651

Course Website: <http://www.hcii.cmu.edu/courses/interaction-design-studio> (<http://www.hcii.cmu.edu/courses/interaction-design-studio/>)

05-651 Interaction Design Studio I

Fall: 12 units

This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to: -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-670 Digital Service Innovation

Fall: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters

With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with the permission of the instructor. Prerequisites: 15-112 and (15-121 or 15-150 or 15-210 or 15-122) and (05-891 or 05-610) and (05-651 or 05-650 or 05-652 or 05-617 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units

The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, high school, postsecondary, and adult education will be discussed and related to relevant state, national, and international standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, schools, and social systems. Assignments will emphasize linking goals - instruction - assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. Undergraduates are invited to take this course with special permission from Dr. Lauren Herckis.

05-823 E-Learning Design Principles and Methods

Fall: 12 units

This course is about e-learning design principles, the evidence and theory behind them, and how to apply these principles to develop effective educational technologies. It is organized around the book "e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning" by Clark and Mayer with further readings drawn from cognitive science, educational psychology, and human-computer interaction. You will learn design principles 1) for combining words, audio, and graphics in multimedia instruction, 2) for combining examples, explanations, practice and feedback in online support for learning by doing, and 3) for balancing learner versus system control and supporting student metacognition. You will read about the experiments that support these design principles, see examples of how to design such experiments, and practice applying the principles in educational technology development.

Course Website: http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013#Course_Details (http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013/#Course_Details)

05-839 Interactive Data Science

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-840 Tools for Online Learning

Fall: 12 units

In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

Software Societal Systems Courses**08-200 Ethics and Policy Issues in Computing**

Spring: 9 units

In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers

Fall and Spring: 6 units

This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

Language Technologies Institute Courses**11-291 Applied Computational Intelligence Lab**

Intermittent: 9 units

What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.

Prerequisites: 15-122 Min. grade C and 21-127 Min. grade C

11-324 Human Language for Artificial Intelligence

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice

Fall and Spring: 12 units

Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-345 Undergrad Independent Study

All Semesters

No course description provided.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches

Spring: 12 units

The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-390 LTI Minor Project - Juniors

All Semesters: 12 units

No course description provided.

11-411 Natural Language Processing

Intermittent: 12 units

This course is about a variety of ways to represent human languages (like English and Chinese) as computational systems, and how to exploit those representations to write programs that do neat stuff with text and speech data, like translation, summarization, extracting information, question answering, natural interfaces to databases, and conversational agents. This field is called Natural Language Processing or Computational Linguistics, and it is extremely multidisciplinary. This course will therefore include some ideas central to Machine Learning and to Linguistics. We'll cover computational treatments of words, sounds, sentences, meanings, and conversations. We'll see how probabilities and real-world text data can help. We'll see how different levels interact in state-of-the-art approaches to applications like translation and information extraction. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science. Prerequisite: 15-122

11-422 Grammar Formalisms

Spring: 12 units

TBA

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constr. Artif. Lang.

Spring: 12 units

Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. <http://tts.speech.cs.cmu.edu/11-823/> Course Website: <http://tts.speech.cs.cmu.edu/11-823/> (<http://tts.speech.cs.cmu.edu/11-823/>)

11-439 Designing Around Patents on Machine Learning and NLP Technology

Spring: 9 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-441 Machine Learning for Text and Graph-based Mining

Fall and Spring: 9 units

This course provides a comprehensive introduction to the theory and implementation of algorithms for organizing and searching large text collections. The first half of the course studies text search engines for enterprise and Web environments; the open-source Indri search engine is used as a working example. The second half studies text mining techniques such as clustering, categorization, and information extraction. Programming assignments give hands-on experience with document ranking algorithms, categorizing documents into browsing hierarchies, and related topics.

11-442 Search Engines

Fall: 9 units

This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.

Course Website: <http://boston.lti.cs.cmu.edu/classes/11-642/>

11-485 Introduction to Deep Learning

Intermittent: 9 units

Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.

Prerequisites: 15-112 and 21-120 and 21-241

11-488 Concepts in Digital Multimedia and Cyber Forensics

Spring: 12 units

This course covers the use of computational methods in crime investigation (forensics) and prevention (intelligence). In almost all areas of forensics and intelligence, computational methods continue to aid, and sometimes entirely replace, human expertise in tracking crime. This is desirable since automation can address the problems associated with scale and global crime linkage through diverse data computational tools can potentially overcome and surpass human capabilities for crime investigation. This course is of a cross-disciplinary nature. It amalgamates knowledge from criminology, forensic sciences, computer science, statistics, signal processing, machine learning, AI, psychology, medicine and many other fields. Students from all departments and schools are welcome to take this course.

Course Website: <https://forensics-ai.github.io/gh-syllabus/>**11-490 LTI Minor Project - Seniors**

All Semesters: 12 units

No course description provided.

11-492 Speech Processing

Spring: 12 units

Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, speech synthesis systems and integrate them to create a speech interface. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.

Prerequisite: 15-210

11-546 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units

Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University's Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry's need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with an equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: <https://luimagroup.github.io/appliedlegalanalytics/>**11-590 LTI Minor Project - Advanced**

All Semesters: 12 units

No course description provided.

11-603 Python for Data Science

Summer: 12 units

Students learn the concepts, techniques, skills, and tools needed for developing programs in Python. Core topics include types, variables, functions, iteration, conditionals, data structures, classes, objects, modules, and I/O operations. Students get an introductory experience with several development environments, including Jupyter Notebook, as well as selected software development practices, such as test-driven development, debugging, and style. Course projects include real-life applications on enterprise data and document manipulation, web scraping, and data analysis.

Course Website: <https://canvas.andrew.cmu.edu>**11-624 Human Language for Artificial Intelligence**

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-630 MCDS Practicum Internship

Summer

The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program.

11-639 Designing Around Patents on Machine Learning and NLP Technology

Spring: 12 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students' software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the students' skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithms' performance as possible. In essence, students will view the presence of particular patents as a design constraint, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-646 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units

Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University's Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry's need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with an equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: <https://luimagroup.github.io/appliedlegalanalytics/>**11-661 Language and Statistics**

Fall: 12 units

Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp; stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: <http://www.cs.cmu.edu/~roni/11661/>**11-667 Large Language Models Methods and Application**

Fall: 12 units

This course provides a broad foundation for understanding, working with, and adapting existing tools and technologies in the area of Large Language Models like BERT, T5, GPT, and others. It begins with a short history of the area of language models and quickly transitions to a broad survey of the area, offering exposure to the gamut of topics including systems, data, data filtering, training objectives, RLHF/instruction tuning, ethics, policy, evaluation, and other human-facing issues. Students will delve into Transformer architectures more broadly and how they work, as well as exploring the reasons why they are better than LSTM-based seq2seq, decoding strategies, etc. Students will learn through readings and hands-on assignments where they will explore techniques for pretraining, attention, prompting, etc. They will then apply these skills in a semester-long course project, making use of locally sourced model instances that offer the opportunity to explore behind the curtain of commercial APIs. Prerequisites: 11-711 or 11-785 or 11-685 or 10-601 or 10-701

11-696 MIIS Capstone Planning Seminar

Spring: 6 units

The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquire data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-697 Introduction to Question Answering

Fall: 12 units

The Introduction to Question Answering course provides a chance for hands-on, in-depth exploration of core algorithmic approaches to question answering (QA) for students who haven't worked on a QA system before.

11-711 Advanced Natural Language Processing

Fall: 12 units

Advanced natural language processing is an introductory graduate-level course on natural language processing aimed at students who are interested in doing cutting-edge research in the field. In it, we describe fundamental tasks in natural language processing such as syntactic, semantic, and discourse analysis, as well as methods to solve these tasks. The course focuses on modern methods using neural networks, and covers the basic modeling and learning algorithms required therefore. The class culminates in a project in which students attempt to reimplement and improve upon a research paper in a topic of their choosing.

11-716 Graduate Seminar on Dialog Processing

All Semesters: 6 units

Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons

All Semesters: 12 units

Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms

Intermittent: 12 units

The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational linguistics, language technologies, and linguistics. We hope to have students from a variety of disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorical Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-724 Human Language for Artificial Intelligence

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

Course Website: <http://www.lti.cs.cmu.edu/Courses/11-724-desc.htm>**11-731 Machine Translation and Sequence-to-Sequence Models**

Spring: 12 units

Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-737 Multilingual Natural Language Processing.

Fall: 12 units

11737 Multilingual Natural Language Processing is an advanced graduate-level course on natural language processing techniques applicable to many languages. Students who take this course should be able to develop linguistically motivated solutions to core and applied NLP tasks for any language. This includes understanding and mitigating the difficulties posed by lack of data in low-resourced languages or language varieties, and the necessity to model particular properties of the language of interest such as complex morphology or syntax. The course will introduce modeling solutions to these issues such as multilingual or cross-lingual methods, linguistically informed NLP models, and methods for effectively bootstrapping systems with limited data or human intervention. The project work will involve building an end-to-end NLP pipeline in a language you don't know.

Course Website: <https://www.cs.cmu.edu/~leili/course/11737mnlp23fa/>**11-739 Designing Around Patents on Machine Learning and NLP Technology**

Spring: 12 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students' software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraint, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-741 Machine Learning for Text and Graph-based Mining

Fall and Spring: 12 units

This course studies the theory, design, and implementation of text-based information systems. The Information Retrieval core components of the course include statistical characteristics of text, representation of information needs and documents, several important retrieval models (Boolean, vector space, probabilistic, inference net, language modeling), clustering algorithms, automatic text categorization, and experimental evaluation. The software architecture components include design and implementation of high-capacity text retrieval and text filtering systems. A variety of current research topics are also covered, including cross-lingual retrieval, document summarization, machine learning, topic detection and tracking, and multi-media retrieval. Prerequisites: Programming and data-structures at the level of 15-212 or higher. Algorithms comparable to the undergraduate CS algorithms course (15-451) or higher. Basic linear algebra (21-241 or 21-341). Basic statistics (36-202) or higher.

11-747 Neural Networks for NLP

All Semesters: 12 units

Neural networks provide powerful new tools for modeling language, and have been used both to improve the state-of-the-art in a number of tasks and to tackle new problems that were not easy in the past. This class will start with a brief overview of neural networks, then spend the majority of the class demonstrating how to apply neural networks to natural language problems. Each section class will introduce a particular problem or phenomenon in natural language, describe why it is difficult to model, and demonstrate several models that were designed to tackle this problem. In the process of doing so, the class will cover different techniques that are useful in creating models, including handling variably sized and structured sentences, efficient handling of large data, semi-supervised and unsupervised learning, structured prediction, and multilingual modeling. There are no official pre-requisites, but a natural language processing course such as 11-411, 11-611, or 11-711, or other experience with implementing natural language processing models is highly recommended.

11-751 Speech Recognition and Understanding

All Semesters: 12 units

The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis

Spring: 12 units

The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knowledge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing

Fall: 12 units

Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects and #8212; characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics

Fall: 12 units

Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: <http://www.cs.cmu.edu/~roni/11761/>**11-762 Language and Statistics II**

Fall: 12 units

This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746). Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data

Fall: 12 units

This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: <http://www.cs.cmu.edu/~nasmith/SPFLODD/>**11-776 Multimodal Affective Computing**

Fall: 12 units

Humans are highly social creatures and have evolved complex mechanisms for signaling information about their thoughts, feelings, and intentions (both deliberately and reflexively). In turn, humans have also evolved complex mechanisms for receiving these signals and inferring the thoughts, feelings, and intentions of others. Proper understanding of human behavior, in all its nuance, requires careful consideration and integration of verbal, vocal, and visual information. These communication dynamics have long been studied in psychology and other social sciences. More recently, the field of multimodal affective computing has sought to enhance these studies using techniques from computer science and artificial intelligence. Common topics of study in this field include affective states, cognitive states, personality, psychopathology, social processes, and communication. As such, multimodal affective computing has broad applicability in both scientific and applied settings ranging from medicine and education to robotics and marketing. The objectives of this course are: (1) To give an overview of the components of human behavior (verbal, vocal, and visual) and the computer science areas that measure them (NLP, speech processing, and computer vision) (2) To provide foundational knowledge of psychological constructs commonly studied in multimodal affective computing (e.g., emotion, personality, and psychopathology) (3) To provide practical instruction on using statistical tools to study research hypotheses (4) To provide information about computational predictive models that integrate multimodal information from the verbal, vocal, and visual modalities (5) To give students practical experience in the computational study of human behavior and psychological constructs through an in-depth course project

11-777 Multimodal Machine Learning

Fall: 12 units

Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation and mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCLL and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: <https://piazza.com/cmu/fall2018/11777/home> (<https://piazza.com/cmu/fall2018/11777/home/>)

11-792 Intelligent Information Systems Project - HEINZ STUDENTS ONLY

Spring: 12 units

The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students. Prerequisites: 15-393 or 11-791

11-851 Talking to Robots

Fall

Household robots need to move beyond simple programmed tasks like those a roomba, and become full-fledged digital assistants. A robotic agent that exists (physically) in the world, gains access to rich and personalized knowledge of its environment. How much do things weigh? What's fragile? Where you store the extra chocolates that you don't want anyone to find because they are just for you. Building an agent that can accomplish tasks requires the integration of a diverse set of technologies and engineering. Language models, SLAM, semantic mapping, task planning, understanding affordances, and end effector control. This course will cover both foundational works in grounding language to action and analyze (or reimplement) state-of-the-art Large Language Model based task planners.

Course Website: <https://talkingtorobots.com/11-851/>

11-877 Advanced Topics in Multimodal Machine Learning

Spring

This course is designed to be a graduate-level course covering recent research papers in multimodal machine learning, a vibrant multi-disciplinary research field which studies modeling, alignment, and fusion of heterogeneous data from multiple modalities, including language, vision, and acoustic. The course will focus on discussions and understanding of recent research papers in this field. Students are expected to have already taken 11-777 Multimodal Machine Learning course or have equivalent research experience (instructor approval required). The course is planned for 6 credit units. Optionally, students can register for 12 credit units, with the expectation to do a comprehensive research project as part of the semester. These course projects are expected to be done in teams, with the research topic to be in the realm of multimodal machine learning and pre-approved by the course instructors.

Prerequisite: 11-777 Min. grade C

11-927 MIIIS Capstone Project

Fall: 36 units

The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

Machine Learning Courses

10-301 Introduction to Machine Learning (Undergrad)

Fall and Spring: 12 units

Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10301 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation and amp; the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets and amp; Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10315.) Prerequisites (strictly enforced): strong quantitative aptitude, college probability and amp; statistics course, and programming proficiency. For learning to apply ML practically and amp; effectively, without the above prerequisites, consider 11344/05834 instead. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field. Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (36-217 Min. grade C or 36-218 Min. grade C or 15-359 Min. grade C or 36-219 Min. grade C or 15-259 Min. grade C or 36-225 Min. grade C or 36-235 Min. grade C or 21-325 Min. grade C)

Course Website: <http://mlcourse.org>

10-315 Introduction to Machine Learning (SCS Majors)

Fall and Spring: 12 units

Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results.

Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (36-218 Min. grade C or 15-359 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 36-235 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 15-259 Min. grade C) and (21-242 Min. grade C or 21-241 Min. grade C or 21-240 Min. grade C)

Course Website: <https://goo.gl/mmR2eL> (<https://goo.gl/mmR2eL/>)

10-335 Art and Machine Learning

Intermittent: 12 units

Ars, the Latin origin of the word art, means Art and Science. These two fields, which have been separated for a long time, are joining back together in many areas. One of those junctions is where Art and Machine Learning meet. Art in recent years has been moving forward along with the rise of new technologies and scientific discoveries. Machine Learning (ML) is one of the most cutting edge advancements in Computer Science. The popularity and accessibility of frameworks such as Google's Deep Dream system, Pikazo the neural style transfer, Kulitta AI Music Generation Framework, Deep Mind's WaveNet, Sony's Flow Machines, and recurrent neural network based language models brought great attention to the marriage of Art and ML methods. The number of ML applications that mimic famous artworks, e.g. The Next Rembrandt project, or even create original artworks such as the robot artist TAIDA's paintings, is rapidly growing. Increasing number of artists are also attempting to use ML methods in their artworks. This course is project-based and aims to introduce the crossroad of Art and Machine Learning to the broad range of students including both Art and Computer Science majors. We will offer the knowledge of examples, technologies, and issues that connect Art and Machine Learning to the students. Students will study example codes and produce creative applications/artworks using ML methods. Students do not need to have pre-existing knowledge of Machine Learning or experience of Art practice. Students are required to have basic understanding of Python and be open-minded, for example, open to learn the necessary mathematical background and open to discussions on conceptual development and artistic value of their projects.

10-403 Deep Reinforcement Learning & Control

Spring: 12 units

This course brings together many disciplines of Artificial Intelligence (including computer vision, robot control, reinforcement learning, language understanding) to show how to develop intelligent agents that can learn to sense the world and learn to act by imitating others, maximizing sparse rewards, and/or satisfying their curiosity.

Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

Course Website: <https://cmudeeprl.github.io/Spring202010403website/>

10-405 Machine Learning with Large Datasets (Undergraduate)

Spring: 12 units

Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data pre-processing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.

Prerequisites: (15-214 or 15-210 or 15-211 or 17-214) and (10-715 or 10-701 or 10-601 or 10-401 or 10-315 or 10-301)

Course Website: <https://10605.github.io/>

10-414 Deep Learning Systems: Algorithms and Implementation

Intermittent: 12 units

The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.

Prerequisites: (15-513 Min. grade C or 15-213 Min. grade C) and (21-241 Min. grade C or 21-240 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (10-715 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C)

10-417 Intermediate Deep Learning

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

Course Website: <https://deeplearning-cmu-10417.github.io>

10-418 Machine Learning for Structured Data

Intermittent: 12 units

A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.

Prerequisites: 10-301 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C

10-422 Foundations of Learning, Game Theory, and Their Connections

Intermittent: 12 units

In the past decades, researchers have discovered a number of important and deep connections between machine learning theory and algorithmic game theory. This course will explore these connections, both introducing fundamental topics in each area and describing how ideas from each area can shed light on the other.

Prerequisites: (36-217 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C) and 15-251 Min. grade C and (21-241 Min. grade C or 21-242 Min. grade C or 21-240 Min. grade C)

10-425 Introduction to Convex Optimization

Intermittent: 12 units

As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.

Prerequisites: (21-241 Min. grade C or 21-240 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (21-254 Min. grade C or 11-485 Min. grade C or 21-256 Min. grade C or 21-259 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C) and 15-122 Min. grade C

Course Website: <https://www.cs.cmu.edu/~mgormley/courses/10425>
(<https://www.cs.cmu.edu/~mgormley/courses/10425/>)

10-500 Senior Research Project

All Semesters

Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study

All Semesters

Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning

Fall and Spring: 12 units

This course provides a place for students to practice the necessary mathematical background for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)

Fall and Spring: 12 units

Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10601 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation and amp; the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets and amp; Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam, and possibly a project (details may vary depending on the section). 10601 is recommended for quantitative master's and amp; PhD students outside MLD. Prerequisites (strictly enforced): strong quantitative aptitude, college prob and amp;stats course, and programming proficiency. For learning to apply ML practically and amp; effectively, without the above prerequisites, consider 11344/05834 instead. If you are unsure whether you have sufficient mathematical background to do well in this course, you should consider taking the minis 10-606 and 10-607 Mathematical and Computational Foundations for Machine Learning. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (15-259 Min. grade C or 36-217 Min. grade C or 36-218 Min. grade C or 36-235 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 15-359 Min. grade C)

Course Website: <http://mlcourse.org>

10-605 Machine Learning with Large Datasets

Fall and Spring: 12 units

Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, an algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills. Prerequisites: (15-214 or 15-210 or 17-214 or 15-211) and (10-715 or 10-301 or 10-315 or 10-401 or 10-701 or 10-601)

Course Website: <https://10605.github.io/>

10-606 Mathematical Foundations for Machine Learning

Fall: 6 units

This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning

Fall: 6 units

This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning

Intermittent: 12 units

Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-715 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-613 Machine Learning Ethics and Society

Intermittent: 12 units

The practice of Machine Learning (ML) increasingly involves making choices that impact real people and society at large. This course covers an array of ethical, societal, and policy considerations in applying ML tools to high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which ML can lead to or amplify problematic decision-making practices (e.g., those exhibiting discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of ML, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of ML in socially consequential domains.

Prerequisites: 10-301 or 10-315 or 10-715 or 10-601 or 10-701

Course Website: <http://www.cs.cmu.edu/~hheidari/ml-es-spring-23.html>**10-617 Intermediate Deep Learning**

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C

Course Website: <https://deeplearning-cmu-10417.github.io>**10-618 Machine Learning for Structured Data**

Intermittent: 12 units

A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-601 Min. grade C or 10-401 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C

10-701 Introduction to Machine Learning (PhD)

Fall and Spring: 12 units

Machine learning studies the question "How can we build computer programs that automatically improve their performance through experience?" This includes learning to perform many types of tasks based on many types of experience. For example, it includes robots learning to better navigate based on experience gained by roaming their environments, medical decision aids that learn to predict which therapies work best for which diseases based on data mining of historical health records, and speech recognition systems that learn to better understand your speech based on experience listening to you. This course is designed to give PhD students a thorough grounding in the methods, mathematics and algorithms needed to do research and applications in machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong numerate background can catch up and fully participate. You can evaluate your ability to take the course via a self-assessment exam that will be made available to you after you register. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601." This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML. If you are unsure whether you have sufficient mathematical background to do well in this course, you should consider taking the minis 10-606/10-607 Mathematical Background for Machine Learning. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (15-259 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C)

10-702 Statistical Machine Learning

Spring: 12 units

Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term "statistical" in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the "art" of designing good learning algorithms and the "science" of analyzing an algorithm's statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation. Prerequisites: (10-705 or 36-705) and (10-701 or 10-715)

Course Website: <http://www.stat.cmu.edu/~larry/=sml/>

10-703 Deep Reinforcement Learning & Control

Spring: 12 units

This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one fourth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards. Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.

Prerequisites: 10-601 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-301 Min. grade B or 10-315 Min. grade B or 10-401 Min. grade B

Course Website: <https://cmudeeprl.github.io/703website/>

10-707 Advanced Deep Learning

Fall and Spring: 12 units

Models that are capable of extracting complex, hierarchical representations from high-dimensional data lie at the core of solving many ML and AI domains, such as visual object recognition, information retrieval, natural language processing, and speech perception. While the usefulness of such deep learning techniques is undisputed, our understanding of them is still in many ways nascent. The goal of this course is to introduce students to recent and exciting developments (both theoretical and practical) in these methods. This is an advanced graduate course, designed for Masters and Ph.D. level students, and will assume a substantial degree of mathematical maturity. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.

Prerequisites: 10-401 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-708 Probabilistic Graphical Models

Spring: 12 units

Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.

Prerequisites: 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C

Course Website: <https://andrejristeski.github.io/10708-22/>

10-715 Advanced Introduction to Machine Learning

Fall: 12 units

Machine Learning is the primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory. Students entering the class are expected to have a pre-existing strong working knowledge of linear algebra, probability, statistics, and algorithms. The course will also involve programming in Python. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). You can find a webpage to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (15-359 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C)

Course Website: [https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/](https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/index.html)
[index.html \(https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/\)](https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/)

10-716 Advanced Machine Learning: Theory and Methods

Spring; 12 units

Advanced Machine Learning is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover advanced machine learning methods such as nonparametric and deep compositional approaches to density estimation and regression; advanced theory such as fundamentals of clustering, classification, boosting; theory and methods at the intersection of statistical and computational efficiency; as well as vignettes of theoretical results on some hot topics such as robustness and explainability.

Prerequisites: (10-701 Min. grade C or 10-715 Min. grade C) and (36-705 Min. grade C or 36-700 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~pradeep/716/>

10-725 Convex Optimization

Intermittent; 12 units

Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.

Prerequisites: (21-341 Min. grade C or 21-242 Min. grade C or 10-606 Min. grade C or 21-671 Min. grade C or 21-240 Min. grade C) and (21-268 Min. grade C or 21-259 Min. grade C or 21-254 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

Course Website: <https://www.stat.cmu.edu/~siva/teaching/725/>

10-737 Creative AI

Intermittent

Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: <http://kangeunsu.com/creativeai19f/>

10-745 Scalability in Machine Learning

Fall; 12 units

The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.

Prerequisites: 10-301 Min. grade B or 10-315 Min. grade B or 10-401 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-601 Min. grade B

10-777 Historical Advances in Machine Learning

Intermittent; 12 units

We will read (before class) and discuss (in class) a variety of historically important papers in ML (and to some extent AI). Not all of these were initially published in the ML/AI literature (eg: Bellman in math, VC in probability, bandits in statistics, fuzzy sets in control, optimization work in OR, etc, but now play central roles in ML and/or AI). Since "historical" is always ambiguous, we're going to go with "presented/published before the instructor was born" as a definition (pre-1988). While the content of the paper will be the primary focus, we will also attempt to understand the research context in which the paper was written. For example, what questions were other researchers asking at the time? Was the paper immediately recognized as a breakthrough or did it take a long time? Do we view the contents of the paper today as "obvious in hindsight" or is there still a lot of material in the paper that is nontrivial and even surprising or underappreciated? Who was the author, were they already relatively well known when they wrote the paper, or was it the paper itself that made them famous? What else did these authors work on before/after the paper?

Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-805 Machine Learning with Large Datasets

Spring; 12 units

Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data preprocessing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course (10-301, 10-315, 10-601, 10-701, or 10-715) is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.

Prerequisites: (17-214 or 15-211 or 15-210 or 15-214) and (10-301 or 10-315 or 10-701 or 10-401 or 10-601 or 10-715)

Course Website: <https://10605.github.io/>

10-806 Foundations of Machine Learning and Data Science

Fall: 12 units

This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include: - Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: <http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html> (<http://www.cs.cmu.edu/~ninamf/courses/806/10-806->)

10-807 Topics in Deep Learning

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models and #8212; models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.

Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C

10-822 Presentation Skills

Fall and Spring: 6 units

This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy

Spring: 12 units

Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/pr propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: <https://www.andrew.cmu.edu/user/jweiss2/mlp/>

10-831 Special Topics in Machine Learning and Policy

Spring: 6 units

Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: <http://www.cs.cmu.edu/~neill/courses/90921-S10.html>

Course Website: <http://www.cs.cmu.edu/~neill/courses/90921-S10.html>

Robotics Courses

16-161 ROB Freshman Seminar: Artificial Intelligence and Humanity

Fall and Spring: 9 units

In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-211 Foundational Mathematics of Robotics

Fall: 12 units

This course will cover core mathematics concepts used in many advanced robotics courses at the RI. Perhaps unlike prior courses in math, the focus of this class will be to ground concepts in robotics algorithms or applications. For example: How to move and manipulate objects in 3D space (coordinate transforms, rotations). How to move an articulated robots end-effector in Cartesian space (Jacobians, gradient optimization). How to have a robot learn to recognize a vision input (neural networks, back propagation). How to plan navigate a robot optimally (dynamic programming, A* Search). Prerequisites: 21-122 and 21-241 and (21-325 or 36-225 or 36-218 or 15-259)

16-223 IDEATe Portal: Creative Kinetic Systems

Fall: 10 units

The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDEATe Portal Course open to students from all colleges. For students choosing to follow an IDEATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: <https://courses.ideate.cmu.edu/16-223> (<https://courses.ideate.cmu.edu/16-223/>)

16-224 IDEATe: Re-Crafting Computational Thinking with Soft Technologies

Fall: 6 units

This course focuses on teaching introductory concepts of Robotics, Mechatronics, and Computer Science using an arts-based approach. During the course, students will build their own weaving robot, program it, and learn how weaving art is connected to computer programming and matrix mathematics. Students will also learn the history of weaving, how to design beautiful patterns, and how to extract the features of those patterns into mathematical equations and computer programs.

16-235 Fantastic Robots and How to Fold Them

Spring: 9 units

This course will focus on the basics of robotics through a hands-on approach. Students will build their own robots by designing a mechanical structure and embedding actuators, sensors, and controllers. They will then use these robots to solve a simple maze with obstacles. The course content will be delivered through lectures, workshops, and a course-long team project. In classical robotics, we explore the three main behaviors of robots through the work frame of "sense-plan-act". Robots are more than just these behaviors, and students will learn about how to make the physical embodiments of robots through an overview of design and manufacturing techniques for robot mechanisms. Students will be able to make their own mechanisms, improve the system through hardware or software, and learn how to analyze the kinematics and dynamics of these mechanisms to understand and control the motion.

Prerequisites: 15-112 Min. grade C or 15-110 Min. grade C or 15-104 Min. grade C

16-264 Humanoids

Spring: 12 units

This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: <http://www.cs.cmu.edu/~cga/humanoids-ugrad/>

16-299 Introduction to Feedback Control Systems

Spring: 12 units

This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with robotics minor.

Prerequisites: 15-122 and 21-122

Course Website: <http://www.cs.cmu.edu/~cga/controls-intro/>

16-311 Introduction to Robotics

Spring: 12 units

This course presents an overview of robotics in practice and research with topics including vision, machine learning, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct LEGO robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students usually work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. Groups are typically self-formed except for the first lab. This course will also expose students to some of the contemporary happenings in robotics, including current robotics research, applications, robot contests and robots in the news. Students registering for this course must register for both Mon/Wed mornings and Tuesday afternoon sections.

Prerequisites: 21-240 Min. grade C or 24-311 Min. grade C or 18-202 Min. grade C or 21-260 Min. grade C or 21-241 Min. grade C

Course Website: <http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/>

16-322 Modern Sensors for Intelligent Systems

Spring: 12 units

The class aims at introducing sensing technologies for robots and other intelligent systems. The course will cover the physical principles of traditional sensors, sensor calibration and evaluation, signal processing algorithms for different sensors, and examples of sensor applications for robots or other intelligent systems. On the sensing system design part, the course will cover the common sensor fusion design and algorithms, and provide examples of sensing systems for different robots or intelligent systems, such as wearable sensors, self-driving cars, autonomous vehicles, assistant robots, and field robots in extreme conditions. The class will contain lectures, two lab sessions, and a course project.

16-350 Planning Techniques for Robotics

Spring: 12 units

Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: <http://www.cs.cmu.edu/~maxim/classes/robotplanning/>

16-362 Mobile Robot Algorithms Laboratory

Fall: 12 units

This course is an introduction to the theory and algorithms of multirotor vehicle autonomy. Students will work individually to develop a multirotor simulator in Python and C++, add sensors, plan, and perform exploration. Lectures will cover topics to advance the capabilities of the simulator. Homeworks will be designed to increase the autonomy capabilities of the multirotor vehicle. The class will culminate in an individual project that pushes the autonomy capabilities developed throughout the course and may cover multi-robot aerial autonomy, dynamic environment modeling, or advanced planning and control. In order to succeed in the course, students must have a 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and have already mastered at least one object-oriented programming language like C++ or Python. When the course is over, students will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

16-371 Personalized Responsive Environments

Spring: 9 units

[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.

Prerequisites: 60-223 Min. grade C or 18-090 Min. grade C or 15-104 Min. grade C or 62-150 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects

Spring: 12 units

Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: <https://courses.ideate.cmu.edu/16-374> (<https://courses.ideate.cmu.edu/16-374/>)

16-375 IDeATe: Robotics for Creative Practice

Fall: 10 units

Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.

Prerequisites: 60-212 or 99-361 or 15-112 or 15-110 or 60-210 or 15-104

Course Website: <https://courses.ideate.cmu.edu/16-375> (<https://courses.ideate.cmu.edu/16-375/>)

16-376 IDeATe: Kinetic Fabrics

Spring: 10 units

Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: <https://courses.ideate.cmu.edu/16-376> (<https://courses.ideate.cmu.edu/16-376/>)

16-384 Robot Kinematics and Dynamics

Fall: 12 units

Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.

Prerequisites: 24-311 or 21-241 or 18-202 or 15-122 Min. grade C or 16-311

16-385 Computer Vision

Fall and Spring: 12 units

This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.

Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-259 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-256 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 24-282 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-254 Min. grade C and 15-122 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~16385/>

16-397 Art, Conflict and Technology

Spring: 12 units

This course considers the period of violence in Northern Ireland from 1968 to 1998 known as The Troubles, and recent issues pertaining to sovereignty and borders caused by Brexit, Britain's proposed exit from the European Union, as a point of comparison between societies rife with strife, division and predilections to violence. We investigate the ways in which visual art to literature to theatrical performance explores and interrogates societal conflict and emergence from conflict, and how evolving technological systems influence political power dynamics and modes of artistic practice. We will use the legacy of societal conflict in Ireland and Northern Ireland to compare concepts and physical manifestations of borders, barriers and bridges in the region and in global contexts. We will examine fluctuating development of democratic processes in Ireland and Northern Ireland, individual and group public performance, and the influence of technologically crude and highly sophisticated tools on communities emerging from strife. We will use our analytical lens to focus on figurative and literal borders, barriers and bridges to explore work produced in Belfast, Derry and Dublin, alongside circumstances and artistic practice in present-day Pittsburgh, Ciudad Juarez, Jerusalem and Soweto. On a visit to Ireland and Northern Ireland over spring break, students will meet with artists, writers, legislators, community organizers, academics and ex-combatants, to learn about their past experience and current motivations. Students will analyze artistic practice, peacekeeping initiatives and performance of identity in relation to the historical framework from which it emerges in Ireland and Northern Ireland. We will use this foundation as a point of comparison to practices throughout the world. Students will process their experience and developing analytical skills by documenting their responses through original creative work.

16-421 Vision Sensors

Spring: 12 units

This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundred year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.

Prerequisites: 21-241 and 21-111

Course Website: <http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/>

16-423 Designing Computer Vision Apps

Fall: 12 units

Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc. Prerequisites: (15-213 and 21-240) or (15-213 and 21-241) or (18-213 and 18-202)

Course Website: <http://16423.courses.cs.cmu.edu>**16-425 Medical Image Analysis**

Spring: 12 units

Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/**16-441 Advanced CP/SIS: Urban Intervention**

Fall and Spring: 12 units

This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering

Fall: 12 units

Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration. Prerequisites: 16-311 Min. grade B and (18-370 Min. grade B or 16-299 Min. grade B or 24-451 Min. grade B)

16-455 IDEaTE: Human-Machine Virtuosity

Spring: 12 units

[IDEaTE course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: <https://courses.ideate.cmu.edu/16-455> (<https://courses.ideate.cmu.edu/16-455/>)**16-456 Reality Computing Studio**

Fall: 12 units

[IDEaTE collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: <http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/>**16-457 Reality Computing II**

Spring: 12 units

[IDEaTE collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyr Matikainen).

Course Website: <http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/>

16-461 Experimental Capture

Fall: 9 units

Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.

Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming

Spring: 10 units

This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects and #8212; one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDEaTe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.

Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-112 Min. grade C or 15-104 Min. grade C

16-467 Human Robot Interaction

Spring: 12 units

The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: <http://harp.ri.cmu.edu/courses> (<http://harp.ri.cmu.edu/courses/>)**16-469 Innovation and Shared Prosperity: Community-engagement for change**

Fall: 12 units

How might we, as a community of learners, utilize our collective talents for innovation and shift our society towards greater justice? In this course we will cover the historical and social context of university-community engagement, discuss best practices in engagement efforts, and operationalize emergent strategy alongside design justice principles. Learnings from this course will foster the growth of lifelong dispositions and habits that can empower learners to chart a course for their personal careers that are consonant with community empowerment and societal equity. This class is for individuals interested in pursuing a career at the intersection of technology and societal equity or for individuals who are interested in issues of justice and equity more broadly. Learning methods for this course will include readings, reflections, and in-class discussions. Students in this class will be asked to draw on their own experiences and to explore case studies. We also anticipate that students will directly engage with local community as facilitated through existing connections with the Center for Shared Prosperity.

16-474 Robotics Capstone

Spring: 12 units

In this course students refine the design, build, integrate, test, and demonstrate the performance of the robot they designed in the prerequisite Systems Engineering Course (16-450). The students are expected to continue to apply the process and methods of Systems Engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. In addition, the students learn and apply Project Management techniques to manage the technical scope, schedule, budget, and risks of their project. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover core topics in Project Management and special topics in Systems Engineering. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews approximately at the end of each of the first three months of the semester. For each review, the students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. In addition to that the students hold a special demonstration of their robotic system for the broader Robotics community.

Prerequisite: 16-450 Min. grade C

16-480 IDEaTe: Special Topics: Creative Soft Robotics

Spring: 10 units

This experimental course offers unique topics situated at the intersection of robotics research and the arts, with a specific research focus that varies each semester. In this course, students survey the state of an emerging research area, then design and fabricate experimental systems and artworks on the theme. Students are guided through literature search and technical paper analysis to identify opportunities and techniques. The textual study spans contemporary robotics and arts literature. The project component is research-focused and explores novel techniques in design, fabrication, programming, and control. The project sequence culminates in the collaborative design of expressive robotic systems which match technical innovation with a human need or artistic expression. The initial iteration of the course focuses on soft robotics, an emerging discipline centered on devices constructed from compliant materials that incorporate sensing and actuation. The literature survey spans soft robotics and kinetic sculpture. The projects center on fabricating forms that incorporate actuators and sensors using silicone rubber cast into 3D-printed and laser-cut molds. This course is offered by IDEaTe and this iteration will satisfy minor requirements for IDEaTe Soft Technologies or IDEaTe Physical Computing.

Course Website: <https://courses.ideate.cmu.edu/16-480> (<https://courses.ideate.cmu.edu/16-480/>)**16-595 Undergraduate Independent Study**

All Semesters

For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research

All Semesters

Undergraduate Reading and Research enables students to gain academic credits for conducting independent studies in robotics. Students must work with a robotics faculty advisor to devise a specific objective, activities (such as reading, evaluating, designing, coding, building, or testing robotic systems) and metrics for evaluation of their performance by their advisor.

16-621 MSCV Project I

Spring: 12 units

The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

Course Website: <https://piazza.com/cmu/spring2019/16621> (<https://piazza.com/cmu/spring2019/16621/>)

16-622 MSCV Capstone

Fall: 12 units

The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.

Fall: 12 units

Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.

Prerequisites: 16-720 or 16-385

Course Website: <http://16623.courses.cs.cmu.edu>

16-627 MSCV Seminar

Fall

(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-663 F1Tenth Autonomous Racing

Fall: 12 units

This hands-on, lab-centered course is for senior undergraduates and graduate students interested in the fields of artificial perception, motion planning, control theory, and applied machine learning. It is also for students interested in the burgeoning field of autonomous driving. This course introduces the students to the hardware, software and algorithms involved in building and racing an autonomous race car. Every week, students take two lectures and complete an extensive hands-on lab. By Week 6, the students will have built, programmed and driven a 1/10th scale autonomous race car. By Week 10, the students will have learned fundamental principles in perception, planning and control and will race using map-based approaches. In the last 6 weeks, they develop and implement advanced racing strategies, computer vision and machine learning algorithms that will give their team the edge in the race that concludes the course.

16-664 Self-Driving Cars: Perception & Control

Fall: 12 units

This course will teach the theoretical underpinnings of self-driving car algorithms and the practical application of the material in hands-on labs. Topics will include deep learning, computer vision, sensor fusion, localization, trajectory optimization, obstacle avoidance, and vehicle dynamics.

16-665 Robot Mobility on Air, Land, & Sea

Fall: 12 units

Required core course for MRSD first-year students. Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-675 Manufacturing Futures

Spring: 12 units

The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodology): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

16-682 Robotic Systems Development Project Course II

Fall: 15 units

Required core course for MRSD second-year students. This course is the second semester in a two-semester sequence intended to enable student teams to design and implement robot systems from the requirements development phase through implementation, verification, and demonstration of a working prototype. Teams of 4-5 students continue work on a project provided by industrial and academic partners, refine design requirements, refine or create new subsystems, and integrate and demonstrate the full system.

16-714 Special Topics: Physics-based Simulation in Robotics

Fall: 12 units

special topics physics-based simulation in robotics - description TBD

16-715 Advanced Robot Dynamics and Simulation

Fall: 12 units

This course explores the fundamental mathematics behind modeling the physics of robots, as well as state-of-the-art algorithms for robot simulation. We will review classical topics like Lagrangian mechanics and Hamilton's Principle of Least Action, as well as modern computational methods like discrete mechanics and fast linear-time algorithms for dynamics simulation. A particular focus of the course will be rigorous treatments of 3D rotations and non-smooth contact interactions (impacts and friction) that are so prevalent in robotics applications. We will use numerous case studies to explore these topics, including quadrotors, fixed-wing aircraft, wheeled vehicles, quadrupeds, humanoids, and manipulators. Homework assignments will focus on practical implementation of algorithms and a course project will encourage students to apply simulation methods to their own research.

16-720 Computer Vision

Fall and Spring: 12 units

Section A is a required core course for MRSD first-year students, and Section B is a required core course for MSCV students. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Python programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: <http://www.andrew.cmu.edu/course/16-720/>

16-725 (Bio)Medical Image Analysis

Spring: 12 units

Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/**16-726 Learning-based Image Synthesis**

Spring: 12 units

This course introduces machine learning methods for image and video synthesis. The objectives of synthesis research vary from modeling statistical distributions of visual data, through realistic picture-perfect recreations of the world in graphics, and all the way to providing interactive tools for artistic expression. Key machine learning algorithms will be presented, ranging from classical learning methods (e.g., nearest neighbor, PCA) to deep learning models (e.g., ConvNets, NeRF, deep generative models, including GANs, VAEs, autoregressive models, and diffusion models). Finally, we will discuss image and video forensics methods for detecting synthetic content. In this class, students will learn to build practical applications and create new visual effects using their own photos and videos.

16-730 Robotics Business

Spring: 12 units

This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel and #8212; extracted from the "big plan" and #8212; is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Ethics and Robotics

Intermittent: 12 units

This course contextualizes robotics, AI, and machine learning within cultural conversation, ethics, and power relationships in society. It will draw upon "AI and Humanity" as well as numerous other texts, including Mindless by Simon Head, Drone Theory by Gr and #233;goire Chamayou, and news articles. The course will culminate in team-based design and futuring project addressing the ways in which robotic technologies will influence society and values in the near future. Our target audience is students who will participate in computer science and robotics research and can use this course to inform future research and career decisions.

Course Website: <https://vdean.github.io/16-735-ethics-robotics.html>**16-740 AI for Manipulation**

Spring: 12 units

Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation

Fall: 12 units

Mechanics of Manipulation is a graduate level course that dives into the fundamentals of robotic manipulation. Through this course you will learn the kinematics, statics, and dynamics of robotic manipulators as they interact with the world to accomplish tasks. You will gain experience with the intelligent use of kinematic constraint, gravity, and frictional forces. Additional topics include rigid body mechanics, automatic planning based on mechanics, deformable manipulation, and simulation of dynamic manipulation. Applications of robotic manipulation are drawn from physical human-robot interaction, manufacturing, and other domains.

Course Website: <http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html> (<http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/>)**16-742 Geometry of Locomotion**

Fall: 12 units

This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning. Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning

Spring: 12 units

This is a course about how to make robots move through and interact with their environment with speed, efficiency, and robustness. We will survey a broad range of topics from nonlinear dynamics, linear systems theory, classical optimal control, numerical optimization, state estimation, system identification, and reinforcement learning. The goal is to provide students with hands-on experience applying each of these ideas to a variety of robotic systems so that they can use them in their own research.

Course Website: <http://www.cs.cmu.edu/~cga/dynopt/>

16-748 Underactuated Robots

Fall: 12 units

People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilistic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots

Spring: 12 units

The course is targeted to senior undergraduates and graduate level students. The lectures will develop the fundamentals of this emerging sub-field of robotics by calling on the experience of practitioners, the common themes of the literature, and relevant material from more basic fields such as computer vision, mathematics, and physics.

Course Website: <http://www.frc.ri.cmu.edu/~alonzoteaching/16-761/16-761.html>

16-765 Robotics & AI for Agriculture

Spring: 12 units

Robotics and artificial intelligence technologies have the potential to increase the efficiency, long-term sustainability, and profitability of agricultural production methods. This class will introduce common aspects of agricultural systems, the AI/Robotics tools that are being used to address them, and key research challenges looking forward. Technical topics include IoT sensor networks, in-field computer vision, 3D crop mapping and modeling, mobile robot navigation, and robotic manipulation of plants. Course sessions will be split evenly between lectures by the instructor and student-led discussion of relevant papers from the contemporary research literature.

16-778 Mechatronic Design

Spring: 12 units

Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: <http://www.ece.cmu.edu/courses/items/18578.html>

16-782 Planning and Decision-making in Robotics

Fall: 12 units

Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated Intelligence in Robotics: Vision Language Planning

Intermittent: 12 units

This is a project-oriented course that covers interdisciplinary topics on cognitive intelligence in robotic systems. Cognitive abilities constitute high-level, humanlike intelligence that exhibits reasoning or problem-solving skills. Such abilities as semantic perception, use of language, and task planning can be built on top of low-level robot autonomy. The topics covered generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. The project theme in Spring 2023 is "movie making" that presents various robotics and machine learning challenges ranging from content generation such as scenario generation or scene/video synthesis/editing to robotics automation such as autonomous camera control or autonomous stop-motion control. This course is composed of 50% lectures and 50% seminar classes. The course objectives will also put a special emphasis on learning research skills, e.g., problem formulation, literature review, ideation, evaluation planning, results analysis, and hypothesis verification. The course is discussion intensive, and thus attendance is required.

Course Website: <http://www.cs.cmu.edu/~jeanoh/16-785/>

16-791 Applied Data Science

Spring: 12 units

This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-792 Applied Machine Learning

Intermittent

This course explores the rapidly developing field of machine learning in the context of its pragmatic applications. The domain of Applied Machine Learning strives to achieve three main goals. The first is to build effective models to optimize the efficacy of decision-making. The second is to maximize the utilization of available data so that no important clue is ever missed. The third is to gain or improve an understanding of data and the underlying processes that produce it. Students are required to register for 9 units to receive credit for lectures but may also register for 12 units which will include 3 units of capstone project.

16-820 Advanced Computer Vision

Fall: 12 units

16-820 is a required core course for MSCV students and is intended to move at a slightly faster pace compared to 16-720. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include camera geometry and calibration, multi-view stereo, 3D reconstruction, image detection, segmentation, and tracking, and physics-based vision. The homeworks involve considerable Python programming exercises.

16-823 Physics-based Methods in Vision (Appearance Modeling)

Intermittent: 12 units

Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.

Prerequisites: 16-720 or 16-385 or 16-820 or 15-462

Course Website: <http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/>

16-824 Visual Learning and Recognition

Spring: 12 units

This graduate-level computer vision course focuses on representation and reasoning for large amounts of data (images, videos, associated tags, text, GPS locations, etc.) toward understanding the visual world surrounding us. We will be reading an eclectic mix of classic and recent papers on topics including Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poses), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Multimodal Perception, Language and Vision Models, Deep Generative Models, Efficient Neural Networks, and more. We will cover a wide range of supervised, semi-supervised, self-supervised, and unsupervised approaches for each topic above.

Prerequisites: 16-720 Min. grade B or 16-722 Min. grade B or 10-701 Min. grade B or 16-385 Min. grade B or 15-781 Min. grade B

Course Website: <https://visual-learning.cs.cmu.edu/>

16-825 Learning for 3D Vision

Spring: 12 units

Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-831 Introduction to Robot Learning

Fall and Spring: 12 units

Robots need to make sequential decisions to operate in the world and generalize to diverse environments. How can they learn to do so? This is what we call the "robot learning" problem and it spans topics in machine learning, visual learning and reinforcement learning. In this course, we will learn the fundamentals of topics in machine/deep/visual/reinforcement-learning and how such approaches are applied to robot decision making. We will study fundamentals of: 1) machine (deep) learning with emphasis on approaches relevant for cognition, 2) reinforcement learning: model-based, model-free, on-policy (policy gradients), off-policy (q-learning), etc.; 3) imitation learning: behavior cloning, dagger, inverse RL and offline RL.; 4) visual learning geared towards cognition and decision making including topics like generative models and their use for robotics, learning from human videos, passive internet videos, language models; and 5) leveraging simulations, building differentiable simulations and how to transfer policies from simulation to the real world; 6) we will also briefly touch topics in neuroscience and psychology that provide cognitive motivations for several techniques in decision making. Throughout the course, we will look at many examples of how such methods can be applied to real robotics tasks as well as broader applications of decision making beyond robotics (such as online dialogue agents etc.). The course will provide an overview of relevant topics and open questions in the area. There will be a strong emphasis on bridging the gap between many different fields of AI. The goal is for students to get both the high-level understanding of important problems and possible solutions, as well as low level understanding of technical solutions. We hope that this course will inspire you to approach problems in cognition and embodied learning from different perspectives in your research. (As of 3/21/2023)

Course Website: https://docs.google.com/document/d/15FCdFSLj9uDKQgY__bdQgic0n2cSyyBBedVjKiRFTuM/edit?usp=sharing (https://docs.google.com/document/d/15FCdFSLj9uDKQgY__bdQgic0n2cSyyBBedVjKiRFTuM/edit?usp=sharing)

16-833 Robot Localization and Mapping

Spring: 12 units

Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: <http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018> (<http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018/>)

16-845 Insects and Robots

Fall: 12 units

This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200µm to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation

Spring: 12 units

Research related to hands has increased dramatically over the past decade. Robot hand innovation may be at an all time high, with new materials and manufacturing techniques promoting an explosion of ideas. Hands have become a priority in virtual reality and telepresence. Even the study of how people use their hands is seeing the growth of new ideas and themes. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly dexterous manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, the role of machine learning in grasping and manipulation, and the challenge of uncertainty. We will explore state of the art manufacturing and design techniques, including innovations in soft robotics and embedded sensing. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: <http://graphics.cs.cmu.edu/nsp/course/16899-s18/>

16-855 Special Topics: Tactile Sensing and Haptics

Spring: 12 units

Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans, and provide students with some hands-on experience with the popular touch sensors and devices. On the side of robot sensing, the course will cover the topics on the working principles and designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The human-machine interface is a core part of Virtual Reality (VR) and teleoperation of robots when touch is involved. The course includes lectures, research paper presentation and discussion, and course projects with tactile sensors or haptic devices.

16-873 Spacecraft Design-Build-Fly Laboratory

Fall and Spring: 12 units

Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. Students will engage directly in all aspects of the spacecraft mission lifecycle from initial requirements definition through mission operations. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Students will work in subsystem teams, each focusing on some aspect of the spacecraft, but will be exposed to many different disciplines and challenges. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-878 Special Topic: Advanced Mechatronics Design

Fall: 12 units

This course is designed for students who have a background in mechatronics by having taken a mechatronics design course or through practice. The course will be a combination of laboratories and lectures and will culminate in a class project. The topics covered will be microcontroller hardware subsystems: timer systems, PWM, interrupts; analog circuits, operational amplifiers, comparators, signal conditioning, interfacing to sensors, actuator characteristics and interfacing; C language features for embedded software, register level programming, hardware abstraction layers, event driven programming, state machines, state charts.

16-879 Medical Robotics

Fall: 12 units

This course presents an overview of medical robotics intended for graduate students and advanced undergraduates. Topics include robot kinematics, registration, navigation, tracking, treatment planning, and technical and medical aspects of specific applications. The course will include guest lectures from robotics researchers and surgeons, as well as observation of surgical cases. The course is open to non-majors who have the requisite background.

16-880 Special Topics: Engineering Haptic Interfaces

Spring: 12 units

This course focuses on addressing challenges in the field of haptics from an engineer's perspective. We will begin by studying human haptic perception and an introduction into psychophysics. We will then study the design and control of haptic systems which provide touch feedback to a user. The class format will include lectures, discussion, paper presentations, laboratories and assignments using hardware that will be shipped to the students, and a class project. This class is designed to be a graduate/advanced undergraduate course and requires a background in dynamic systems, mechatronics, and basic programming. Mechanical prototyping, robotics, and feedback control knowledge are useful skills for this class but are not required.

16-881 Seminar Deep Reinforcement Learning for Robotics

Spring: 12 units

Deep RL has a lot of promise to teach robots how to choose actions to optimize sequential decision-making problems, but how can we make deep RL work in the real world? This is a seminar course in which we read papers related to deep learning for robotics and analyze the tradeoffs between different approaches. We will read mostly state-of-the-art papers that were very recently published (e.g. recent CoRL, RSS), but we will also look at some older papers that use different approaches. The goals of the course are to 1) understand what is needed to make deep learning work for robotics 2) analyze the tradeoffs between different approaches. Each class, 2 papers will be presented. These papers will both achieve a similar robotics task but will use different learning-based approaches. The class will discuss these papers and try to understand the strengths and limitations of the approach described in each paper. The list of papers that we will be discussing this year is still to be determined; please see the website for the list of papers that we have used in past semesters: <https://sites.google.com/view/16-881-cmu/paper-lists?authuser=0> The seminar is a great followup course to 16-831, 16-884, 10-403, or 10-703.

Course Website: <https://sites.google.com/view/16-881-cmu/home?authuser=0> (<https://sites.google.com/view/16-881-cmu/home?authuser=0>)

16-882 Integrated Systems Engineering and Project Management

Spring: 12 units

Systems Engineering is a top-down, interdisciplinary, and systematic approach to conceptualizing, developing, using, and retiring systems. Project Management is a bottom-up approach that applies methods, skill, and knowledge to plan, monitor, control, and close out projects. In a broad sense, a system is a construct that consists of elements working together under well-defined requirements to achieve a unique purpose; a project is a finite team activity that aims to create a unique prototype, product, or system at a certain level of fidelity and maturity. In this course students will learn the theory, essential methods, and techniques of systems engineering and project management. They will apply these combined concepts and skills to develop a system of their choosing over the course of the semester, either independently or by collaborating with a team. Even though this course is offered by the Robotics Institute and some of its content will speak to the application of the concepts in robotic applications and systems, this course is open to and suited for all CMU students irrespective of discipline. In addition to graduate students, this course is also suited for juniors and seniors.

16-883 Special Topics: Provably Safe Robotics

Spring: 12 units

Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: <http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html>

16-884 Deep Learning for Robotics

Fall: 12 units

The goal of this course is to study relevant topics towards building intelligent robots that can learn to act and perceive in the real world. The course material should be a self-contained collection of key topics from the intersection of four research areas geared towards this common goal: a) Robot Learning and amp; Deep RL; (b) Computer Vision; (c) Control; (d) Psychology and amp; Neuroscience. This course is geared mainly towards learning and brainstorming. There will be two classes every week. In this first class, instructor will present an in-depth overview of a topic, and then in the second class, students will present instructor-assigned papers related to that topic. There will be no homeworks and just a course project. In the first quarter, we will cover state-of-the-art topics in robot learning (deep RL, inverse RL, etc.) and control (optimal control, dynamic movement primitives, etc.) by studying classical and recent papers in the area. In the second quarter, we will study the role of perception in control and vice-versa to build methods that can learn from high-dimensional raw sensory input. In the third quarter, we will discuss the state of the current understanding of how the brain integrates action and perception. We will also discuss relevant papers from ontogeny (child development literature in Psychology) and phylogeny (evolutionary development literature in Biology) of biological animals that have inspired ideas in learning and robotics. Finally, in the fourth quarter, we will bring these ideas together to brainstorm potential high-level directions that could guide the development of intelligent robots.

16-885 Special Topics: Tactile Sensing and Haptics

Fall: 12 units

Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans. On the side of robot sensing, the course will cover the designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in the human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The course incorporates lectures, research paper presentations, and discussion. The combination of different modules aims to present both the basics and state-of-art research directions in the field.

16-887 Special Topic: Robotic Caregivers and Intelligent Physical Collaboration

Spring: 12 units

Robotics researchers and futurists have long dreamed of robots that can serve as caregivers. In this project-based course, you'll learn about intelligent physical human-robot collaboration and opportunities for robots that contribute to caregiving. You'll gain hands-on experience with teleoperation, autonomy, perception, navigation, manipulation, human-robot interaction, and machine learning. You'll also learn about robot design, collaborative research, and healthcare robotics.

Course Website: <https://zackory.com/rc2023/>

16-888 Special Topic: Foldable Robots: Origami-inspired design meets mechatronics

Intermittent: 12 units

The way we make robots have changed dramatically since the limitations on the material space was removed. Instead of using "nuts-and-bolts" approach that helped us to make robust, rigid, industrial robots, we can make light-weight, compliant, conformable robots out of paper, fabric, and polymers. In this class, we will explore foldable robots with a multifaceted perspective: Kinematics, design, fabrication, control, and application. We will design and manufacture mechanisms for targeted applications, such as manipulation, bio-inspiration, medical, architecture, using laminates with integrated joints and limited number of actuators.

16-889 Special Topic: Learning for 3D Vision

Spring: 12 units

Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-890 Special Topic: Robot Cognition for Manipulation

Intermittent: 12 units

This seminar course will cover a mixture of modern and classical methods for robot cognition. We will review papers related to task planning and control using both symbolic and numeric methods. The goal of this course is to give students an overview of the current state of research on robot cognition.

16-891 Multi-Robot Planning and Coordination

Spring: 12 units

The course provides a graduate-level introduction to the field of multi-robot planning and coordination from both AI and robotics perspectives. Topics for the course include multi-robot cooperative task planning, multi-robot path/motion planning, learning for coordination, coordinating robots under uncertainty, etc. The course will particularly focus on state-of-the-art Multi-Agent Path Finding (MAPF) algorithms that can coordinate hundreds of robots with rigorous theoretical guarantees. Current applications for these technologies will be highlighted, such as mobile robot coordination for warehouses, drone swarm control, and multi-arm assembly. The course includes lectures, research paper presentations and discussions, and course projects.

16-892 Seminar: Multimodal Foundational Models

Fall: 12 units

This course will discuss recent foundation models proposed in the literature, with a focus on vision-language models. Topics include large language models, vision-language models, and vision-audio models. As time allows, this course will also discuss application of such models to visual, audio, and video content generation.

Prerequisite: 16-820

16-895 Understanding and Critiquing Generative Computer Vision

Spring: 12 units

In recent years, there have been significant advances in the field of large-scale generative modeling for visual data, such as DALL-E 2 and Stable Diffusion. This seminar course explores these advances beyond just reading and discussion. The goal is to not only inform state of the art but also develop critical and philosophical thinking among students. The course will involve reading papers, presentations, and discussions. The course will also involve reviewing and developing critical thinking.

Software Societal Systems Courses

17-200 Ethics and Policy Issues in Computing

Fall and Spring: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentions technology choices, formulate smart positions, and support their views with winning arguments.

17-210 Introduction to Social Networks

Spring: 12 units

Course Description What makes a recommendation system on social media effective? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet we have not heard of most of them? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of the free flow of information and fluid connectivity between people that these platforms had envisioned? How do professionals land their dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of social connections that people form on and offline. This course offers an introduction to the study of social networks as a powerful tool for understanding a wide range of questions and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network concepts and their mathematical operationalizations that give social network analysis the versatility for rigorous quantitative analysis. Students will subsequently learn how these building blocks have been applied to analyze and solve a wide range of online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms. Throughout this course, students will work towards a final team project that applies network concepts and measures to either (a) describe and/or explain an empirically puzzling social phenomenon with network data, (b) develop a network data collection pipeline that aims to solve a real-world problem, or (c) build a system utilizing the insights from the course that solves a real-world problem. The following class activities throughout the course are intended to support and augment the final project.

17-213 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units

Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalizations that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

17-214 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.

Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

Course Website: <https://www.cs.cmu.edu/~ckaestne/17214/f2021/>

17-224 Influence, Persuasion, and Manipulation Online

Fall: 9 units

This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-301 Special Topics in Societal Computing: Understanding Cyber Teams

Intermittent: 9 units

Were you the victim of a ransomware attack today? No? Then you should probably thank your cyber security team! Nowadays, nearly everything modern organizations do is protected by some semblance of a cyber team. These cyber teams come in many forms: security operations center, malware analysis, threat emulation, information technology departments, etc. So what do we know about how these cyber teams operate? In this course cyber teams will be studied through the lens of computational organization theory. Different types of cyber teams will be presented with how they operate within the organization. An array of computational organization theory principles will be explored such as network science, information diffusion, policy analysis, and performance theory. A final project will be completed by each student. This project can be of many types such as policy analysis, virtual experimentation, dynamic network analysis, validation, etc. Students will be using the NetLogo scripting language to complete a project. The project will be created, developed, and presented by the student and approved by the instructor.

17-302 Independent Study Mini Undergraduate

Intermittent

Independent Study Mini

17-303 Cryptocurrencies, Blockchains and Applications

Fall and Spring: 9 units

Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies.

17-313 Foundations of Software Engineering

Fall and Spring: 12 units

Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.

Course Website: <https://www.cs.cmu.edu/~ckaestne/17313/>**17-314 Formal Methods**

Fall: 6 units

Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction.

17-322 Agile Methods

Fall: 6 units

Agile methods refers to a number of software development approaches that adopt self-organization, adaptive planning, evolutionary development, frequent delivery and working closely with and incorporating feedback from customers throughout the development process as their principles of operation to achieve responsiveness. This course will introduce students to two well known agile methods: Scrum and Kanban, connecting their practices to established group dynamics and knowledge management theories to explain why they work and under what circumstances

17-323 Quality Assurance

Fall: 6 units

This class is fundamentally about software quality assurance and control. This course will introduce various quality assurance tools and techniques to software engineering students. Students will build their "quality toolbox" not only with useful tools and techniques, but with the knowledge of when those tools should be used, how to evaluate their results, and what assurances they can provide. The key learning objectives of the course include: 1. Understand software quality: how to define it, analyze it, and measure it. 2. Select the proper analytical tool/technique for a given situation and explore how to analyze results. 3. Understand the strengths and weaknesses of different quality assurance techniques, such as software testing, static analysis, code review, and demonstration. 4. Learn to collect, manage, and evaluate quality metrics. 5. Analyze and verify a variety of software properties including, but not limited to, functionality, security, reliability, and performance. 6. Gain experience with real quality assurance tools including static analysis tools, software testing frameworks, and software quality measurement tools

17-324 Advanced Formal Methods

Fall: 6 units

This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

Prerequisite: 17-314 Min. grade B

17-331 Information Security, Privacy, and Policy

Fall: 12 units

As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-332 Software Project Management

Spring: 6 units

Projects are temporary organizations set up to achieve a one time objective in an agreed time frame. They are characterized by requiring the execution of interrelated, normally non repeating activities, by multidisciplinary groups. Because of its temporary nature and the interrelatedness of its activities, projects require prescriptive planning, budgeting, staffing and risk management. This course will introduce student to fundamental project management techniques and tools such as activity planning, milestone planning, estimation, work breakdown structures, critical paths. The course will also look at hybrid methods such as Milestone Driven Agile Execution and Disciplined Agile Delivery.

17-333 Privacy Policy, Law, and Technology

Fall: 9 units

This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-335 Software Architectures

Spring: 6 units

Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications.

17-336 Applied Distributed Systems

Spring: 6 units

Modern computing systems are frequently hosted on the cloud. That is, they are inherently distributed systems. To appropriately build and deploy these systems developers should know not only about development tools such as container management tools but also the structure of the cloud - in particular how it utilizes virtual machines, containers and networks. They should also understand security mechanisms both in the internet and how to authorize users and maintain credentials securely. Finally, to protect the system once it is placed into production, a developer needs to know how to enable the detection of problems during execution through collection and navigation of logs produced by the system. These are the topics covered by this course.

17-340 Green Computing

Intermittent: 9 units

Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, Meche, CEE, EPP and Architecture.

17-346 DevOps and Continuous Integration

Spring: 6 units

DevOps: Engineering for Deployment and Operations": DevOps is the term given to a modern movement to establish practices that significantly reduce the time to production of committed code. This time involves deployment - the period between the completion of the code by the developers and the placing of the code into normal production and dealing with operations issues. Deployment time can be days, weeks, or even months when using normal development practices. Operational issues such as dealing with incidents and errors introduce other delays. Modern internet companies deploy a system multiple or even dozens of times every day. Achieving this velocity requires coordinated process and design activities together with supporting tooling. This course will cover the deployment process and the associated tooling, it will highlight reasons why release schedules can be slow, and it will introduce the practices that are used to enable high velocity deployments. It will also cover the kinds of problems that are created because of high velocity and how modern internet companies deal with these problems. Please note: This is a required course for MSE-SS students. Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.

Prerequisite: 17-336 Min. grade B

17-350 Information Technology Policy: Evidence, Communication, & Advocacy

Spring: 9 units

In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis

Spring: 12 units

This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, interprocedural analysis, dynamic analysis, Hoare Logic and verification, program synthesis and repair, model checking, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, the Theoretical Foundations requirement of the Computer Science master's degree, and the Technical Software Engineering requirement for the Software Engineering minor.

Prerequisites: 15-251 Min. grade C and (15-150 Min. grade C or 17-214)

Course Website: <https://cmu-program-analysis.github.io/>**17-356 Software Engineering for Startups**

Spring: 12 units

Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully.

Prerequisites: 15-213 or 17-514 or 17-214 or 15-214

17-363 Programming Language Pragmatics

Fall: 12 units

This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll.

Prerequisites: 15-150 Min. grade C and (15-251 Min. grade C or 21-228 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-363/>**17-396 Language Design and Prototyping**

Spring: 12 units

Many programmers think of programming languages as having a fixed, standard set of features and #8212;but in fact, languages are being extended all the time, and new languages are constantly being developed, providing great expressive power. In this course, students will learn about techniques for designing and prototyping programming languages. Design topics include language features, a practical approach to semantics, conceptual design techniques, and examples of both general purpose and domain-specific language designs. Prototyping topics include interpreters, source-to-source translators, languages as libraries, and paper prototyping techniques used for lightweight user evaluations. In course assignments, students will practice design and prototyping techniques, implementing prototype languages in several different styles. The course will end with a project in which students design, implement, and evaluate their own programming language.

Prerequisites: 17-514 or 15-213 or 17-214

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-396/>**17-397 Intro to Qualitative Research: Social Media Apps and Video Content Creation**

Spring: 12 units

Short-video apps, such as TikTok, have revealed themselves to be highly accessible and increasingly ubiquitous in regards to online social interaction and are currently the most popular social media among mostly young(er) users. This course focuses on how humans as users interact with and understand social technology and how the use of social media apps is connected to and integrated into our everyday life by asking questions like: What are users' motivations to participate in video creation and sharing on social media? What are their practices, strategies, and routines in creating short-form videos as part of digital online culture? What do they know about socio-technical aspects in using short-video apps and creating short-form video content? How does their understanding of socio-technological aspects influence their use of social media apps? This course is designed to enable students to develop and conduct their own individual research project. For this, students will learn how to design, conduct, and analyze qualitative interviews to research socio-technical, cultural, and political perspectives of usage of and engagement with short-form videos and short-video apps, such as TikTok. The course instructor will closely mentor and supervise students' research projects throughout the semester and will provide expertise and background in qualitative methods and social media research to guide students through the research process.

17-400 Machine Learning and Data Science at Scale

Fall and Spring: 12 units

Datasets are growing, new systems for managing, distributing, and streaming data are being developed, and new architectures for AI applications are emerging. This course will focus on techniques for managing and analyzing large datasets, and on new and emerging architectures for applications in machine learning and data science. Topics include machine learning algorithms and how they must be reformulated to run at scale on petabytes of data, as well as data management and cleaning techniques at scale. In addition to large-scale aspects of data science and machine learning, this course will also cover core concepts of parallel and distributed computing and cloud computing, including hands-on experience with frameworks like Spark, streaming architectures like Flink or Spark Streaming, MLlib, TensorFlow, and more. The course will include programming assignments and a substantial final project requiring students to get hands-on experience with large-scale machine learning pipelines or emerging computing architectures.

Prerequisites: 10-601 or 10-701 or 15-211 or 10-301 or 17-514 or 17-214 or 15-214

Course Website: <http://euro.ecom.cmu.edu/program/courses/tcr17-803>
(<http://euro.ecom.cmu.edu/program/courses/tcr17-803/>)**17-401 Software Engineering for AI-Enabled Systems**

Fall: 12 units

New Course Need Description

Course Website: <https://ckaestne.github.io/seai/>**17-402 AI and Emerging Economies**

Intermittent: 3 units

The course will cover some of the unique aspects of emerging economies as it relates to AI consumption and responsible AI development. The importance of local data and domain knowledge will be illustrated. Germane to budding technologists, entrepreneurs and policy influencers. Multi-disciplinary.

17-405 Grand Challenges in AI: Past, Present and Future

Intermittent: 3 units

Innovative, bold initiatives that capture the imagination of researchers and system builders are often required to spur a field of science or technology forward. A vision for the future of artificial intelligence was laid out by Turing Award winner and Moza Bint Nasser University Professor at CMU, Raj Reddy in his 1988 Presidential address to the Association for the Advancement of Artificial Intelligence. It is time to provide an accounting of the progress that has been made in the field, over the last three decades, toward the challenge goals. While some tasks such as the world-champion chess machine were accomplished in short order, many others, such as self-replicating systems, require more focus and breakthroughs for completion. A new set of challenges for the current decade is also proposed, spanning the health, wealth, and wisdom spheres. The above - plus commentary from half a dozen AI thought leaders - forms the basis of an article in the 2021 Spring Issue of AI Magazine.

17-413 Software Engineering Practicum

Spring: 12 units

This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.

17-415 Software Engineering Reflection

Fall: 6 units

This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-422 Building User-Focused Sensing Systems

Fall and Spring: 12 units

These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

17-428 Machine Learning and Sensing

Fall: 12 units

Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development

Fall and Spring: 12 units

This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, JSON, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Python to register for this course. Students must provide their own computer hardware for this course. Please visit the Course URL for more information about the course.

Prerequisites: 18-613 or 15-513 or 18-213 or 14-513 or 17-214 or 15-214 or 17-514 or 15-213

Course Website: <https://www.cmu-webapps.org/static/index/syllabus.pdf>**17-442 Software Management Theory**

Spring: 6 units

This course will look at software development from an organizational perspective and its designed for students who want to understand the relationship between business context, software development processes, knowledge creation, culture and organizational structure with the purpose of becoming change agents or manage the software development function at the department, business unit level or above. The course will also highlight the need to follow good work principles in order to avoid ethical failures as evidenced by recent affairs

17-443 Quality Management

Spring: 6 units

Managing software quality is a critical part of all software projects. Software engineers must consider quality during every phase of a project from inception to delivery and beyond. This class will introduce students to the managerial challenges of developing high quality software systems. The key learning objectives of this course include: 1. Define a quality management process in the context of a software project. 2. Understand the costs associated with achieving quality goals and not achieving them 3. Understand the tradeoffs required to implement quality assurance techniques. 4. Gain experience using collected quality metrics to inform project-level decisions.

Prerequisite: 17-323 Min. grade B

17-445 Machine Learning in Production

Fall and Spring: 12 units

The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: <https://ckaestne.github.io/seai/>**17-446 DevOps and Continuous Integration**

Spring: 6 units

TBD

Prerequisite: 17-336 Min. grade B

17-450 Crafting Software

Fall and Spring: 12 units

Do you use programming to solve problems in your field of study? Do you know enough to be dangerous, but wish you could be proud of your code? This course aims to provide students with sufficient knowledge and skills to use programming as part of their work. In this class, you will learn how to identify and find problems in your code. You will learn to read, parse, organize, and transform data. We will teach you to write code collaboratively and refine your programs so others can use them. The course will be a mixture of lecture and guided exercise with a recitation focused on hands on instruction. In this course, students are expected to have been exposed to some basic programming concepts, such as variables, if-statements, loops, and arrays. However, students are not expected to have extensive programming experience. This course is not appropriate for students that have completed more than two courses involving programming. We expect students in this class to have diverse backgrounds and experience. Some students will be self-taught, while others will have taken a programming course such as 02-201, 15-110, 95-898, or the library's Software Carpentry workshop. If you have questions about your background and the fit for this class, please don't hesitate to reach out to the instructors.

17-480 API Design and Implementation

Fall and Spring: 12 units

This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason. Prerequisites: 15-213 or 15-214 or 17-214

17-514 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.

Prerequisites: (15-121 Min. grade C or 15-122 Min. grade C) and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C)

Course Website: <https://www.cs.cmu.edu/~ckaestne/17214/f2021/>**17-536 Pervasive and Ubiquitous Computing**

Intermittent: 12 units

Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomp) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good

Spring: 9 units

Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology

Fall: 9 units

A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-599 Advanced Topics in Machine Learning and Game Theory

Fall: 12 units

This course is designed to be a graduate-level course covering the topics at the intersection of machine learning and game theory. Recent years have witnessed significant advances in machine learning and their successes in detection, prediction, and decision-making problems. However, in many application domains, ranging from auction and ads bidding, to entertainment games such as Go and Poker, to autonomous driving and traffic routing, to the intelligent warehouse, to home assistants and the Internet of Things, there is more than one agent interacting with each other. Game theory provides a framework for analyzing the strategic interaction between multiple agents and can complement machine learning when dealing with challenges in these domains. Therefore, in the course, we will introduce how to integrate machine learning and game theory to tackle challenges in multi-agent systems. The course will multiple topics as listed below

Course Website: <https://feifang.info/advanced-topics-in-machine-learning-and-game-theory-fall-2021/>

17-612 Business and Marketing Strategy

Fall: 6 units

This course prepares technically minded students to understand and use essential business concepts in their careers. With this competency, students will be able to make use of, contribute to, and influence the business and marketing decisions that affect engineering and technology decisions, quality, and performance. Students will be better equipped to make business arguments for supporting their product, technology and engineering ideas in their future, too. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. Each student works on a course-long project where they'll conceive and plan a new technology product idea for an existing company. They'll make product, technological, pricing, marketing, and sales decisions to achieve success and are in support of the company's strategy and business decisions. Their work will culminate in building a compelling business case, with financial projections, to persuade the company executives to invest in the product idea.

Course Website: <https://mse.isri.cmu.edu/>**17-619 Introduction to Real-Time Software and Systems**

Intermittent: 12 units

Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computer Simulation of Complex Socio-Technical Systems

Intermittent: 12 units

How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-624 Advanced Formal Methods**

Fall: 6 units

This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

Prerequisite: 17-614 Min. grade B

17-626 Requirements for Information Systems

Fall: 6 units

Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements using scenarios, use cases and mockups.

17-627 Requirements for Embedded Systems

Fall: 6 units

Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements for real-time systems along multiple dimensions, including concurrency, dependability and safety. Prerequisite: 17-614 Min. grade B

17-634 Applied Machine Learning

Spring: 6 units

Autonomous and intelligent systems increasingly rely on automated decision making based on statistical models used for classification or prediction. The practical application of machine learning requires understanding the underlying theoretical assumptions behind a wide variety of statistical models, how to analyze the performance of such models, and how to integrate models into data processing pipelines. This course introduces students to supervised and unsupervised machine learning in the context of software engineering, including the analysis of natural language in bug reports and mobile app reviews. Techniques covered include latent Dirichlet allocation, TF/IDF, naive Bayes, linear regression, decision trees, and random forests.

17-640 IoT, Big Data, and ML: A Hands-on Approach

Intermittent: 12 units

This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-644 Applied Deep Learning

Spring: 6 units

Deep neural networks have made in-roads in virtually every industry, propelled by exponential increases in compute power and fundamental progress in modeling. Knowledge of these models is fast becoming a key asset for software engineers, as current systems are quickly starting to include many neural components, and the practice of software engineering itself is starting to benefit from neural program assistance (incl. automated bug finding, translation between programming languages). This course equips the next generation of software engineers with knowledge of neural models, the software engineering challenges involved in using these, and hands-on experience with their applications. It teaches both a rich vocabulary of general, essential concepts (including architectures), and recent work on applications of these models, aimed primarily at applications for and in software engineering itself. The course includes a group project aimed at constructing a neural solution for an existing application that will be used to teach the various stages (and their pitfalls) of building and deploying deep learners.

17-651 Models of Software Systems

Fall: 12 units

Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MTS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-654 Analysis of Software Artifacts

Spring: 12 units

Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts and #8212;primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power, when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission. Please note: Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.

17-663 Programming Language Pragmatics

Fall: 12 units

This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll. Prerequisites: 15-251 Min. grade C and (15-150 Min. grade C or 21-228 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-363/>**17-670 Virtual Machines and Managed Runtimes**

Fall: 12 units

Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.

Prerequisites: 15-611 or 15-411

17-685 Dynamic Network Analysis

Spring: 12 units

Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class

Course Website: <http://www.casos.cs.cmu.edu/courses/>

17-691 Machine Learning in Practice

Spring: 6 units

As Machine Learning and Artificial Intelligence methods have become common place in both academic and industry environments the majority of resources have focused on methods and techniques for applications. However, there are many considerations that must be addressed when deploying such techniques into practice (or production). The purpose of this course is to cover topics relevant to building a machine learning systems deployed into operations. Such systems have technical requirements including data management, model development, and deployment. However, business/organizational impacts must also be considered. Machine learning systems can be expensive to produce and operate. Students will learn about trade-offs in design, implementation, and expected value. After completing this course, students will: 1. Have the ability to deploy produces with machine learning and AI components; 2. Understand how to implement data pipelines and data engineering systems; 3. Calculate the approximate value provided by a machine learning system to an organization; 4. Understand how to continually assess the value and quality of a deployed machine learning system. Prerequisites: understanding of basic machine learning concepts (i.e. supervised/unsupervised learning). This is a graduate level course.
Prerequisite: 17-634 Min. grade B

17-692 Product Management Essentials

Spring: 6 units

This course prepares technically minded students to understand and use the essential product management concepts and practices at the earliest stage of every new product innovation idea. With this understanding and skills, students will be able to identify and define a worthwhile customer problem to solve, conceive of an innovative, differentiated product solution, design and quantify a compelling customer value proposition and set a strategy for continued innovation and growth. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. You will work on a hands-on, course-long project focused on a problem space selected by the student and approved by the instructor for course fit. PRIORITY is given to students in the Master of Software Engineering (MSE), MS in Engineering and Technology Innovation Management and Master of Information Systems Management degree programs. Make sure you register for the section according to the criteria listed in "Extra Time Commitments."

17-702 Current Topics in Privacy Seminar

Fall and Spring: 3 units

In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-712 Fantastic Bugs and How to Find Them

Spring: 12 units

This advanced course studies the nature of software bugs and security vulnerabilities arising in complex application domains and surveys specialized program analysis + automated testing techniques for identifying such issues proactively. The course will take a tour of various domains such as mobile systems, databases, web browsers, distributed and networked systems, autonomous vehicles, and smart contracts. For each domain, the class will review case studies of high-impact software bugs that have manifested in production and will then discuss state-of-the-art research techniques that aim to uncover such bugs automatically. Apart from the literature review, students will engage significantly with software system design and engineering via hands-on assignments and a semester-long project involving real-world applications and analysis tools for one or more domains. Students completing this course will be able to (a) identify practical challenges of applying well-known program analysis and testing techniques to complex application domains, (b) formulate and leverage domain-specific assumptions for making analysis techniques tractable in a specialized setting, and (c) build practical tools for improving software quality in large-scale systems. The course assumes that students have some background in reasoning about software quality, system security, and/or working with program representations. The course builds upon mathematical principles introduced in foundational classes on program analysis, verification, or compiler design, as well as system design principles encountered in introductory security or software engineering courses. Please check the course website for classes that qualify as sufficient pre-requisites, or contact the instructor to discuss your background.

Course Website: <https://cmu-fantastic-bugs.github.io/>**17-731 Foundations of Privacy**

Fall: 12 units

Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking and targeted advertising).

17-733 Privacy Policy, Law, and Technology

Fall: 12 units

NOTE: Previously offered as 08-733. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-735 Engineering Privacy in Software

Spring: 12 units

Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

17-756 Computational Social Science Research Design and Data Analytics

Spring: 12 units

This course surveys how digital trace data of human activity online, combined with careful research design and data analytics, have led to surprising discoveries and development of novel theoretical explanations in the field of computational social science (CSS). The course has three aims. (a) It is intended to stimulate new ways of formulating research questions on pressing/emerging societal issues of interest (e.g., political polarization, gender representation in open-source software development, decentralized governance based on blockchain technology) given the possibilities afforded by a wide array of digital trace data (e.g., social media, open-source software collaboration, cryptocurrency transactions, satellite imagery). This course will (b) discuss exemplary works in CSS that made novel discoveries or made theoretical and/or methodological breakthroughs and (c) cover practical considerations that commonly arise in a CSS research project cycle. These issues may include, but are not limited to, data collection (sampling methods and bias), repurposing existing datasets that were collected in a different research context, constructing metrics based on theoretical insights, analytic approaches adequate for a given research question (statistical modeling, network analysis, online experiments, simulation-based theory development), big data processing and analytic tools (distributed data processing frameworks, visualization), ethical considerations, and data sharing. In the end, this course will help participants develop "good taste" for theoretically insightful, methodologically creative, and well thought out research, while learning to identify potential pitfalls that could arise in their own research.

17-801 Dynamic Network Analysis

Spring: 12 units

Who knows who? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays an role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class.

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-821 Computer Simulation of Complex Socio-Technical Systems**

Spring: 12 units

How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-880 Algorithms for Private Data Analysis**

Spring: 12 units

We study the following question in this course: How do we perform useful analysis on a data set that contains sensitive information about individuals without compromising the privacy of those individuals? To study this question, we will introduce differential privacy, a framework of designing data analysis algorithms with strong, meaningful, and mathematically provable privacy guarantees. We will survey a set of algorithmic tools that allow us to privately perform a wide range of statistical analyses. Of course, privacy does not come for free, and we will also study some of the fundamental limitations imposed by the requirement of differential privacy. Through the discussion of these results, we will also demonstrate some of the most novel and surprising connections between differential privacy and other areas of theoretical computer science, including machine learning theory, cryptography, convex geometry, and game theory.

SCS Concentrations

The School of Computer Science (SCS) offers concentrations for SCS students in various aspects of computing to provide greater depth to their education. Computer Science majors can substitute an SCS concentration for the minor requirement. Artificial Intelligence and Computational Biology majors can complete an SCS concentration if they wish, but it is not required for these degrees.

Note: At the present time, concentrations are not shown on official transcripts.

SCS Concentrations are currently available to SCS students only and assume these students have taken most/all of the CS core: 15-122/15-150/15-210/15-213/15-251. For SCS students entering in Fall 2018 or later, these students may not pursue a minor within SCS; instead they can pursue the related concentration. For example, instead of pursuing the Software Engineering minor, these SCS students could pursue the new Software Engineering concentration.

Consult the SCS undergraduate concentrations website (<https://www.cs.cmu.edu/undergraduate-concentrations/>) for information about these concentrations as they are approved. For SCS students, consult with your academic advisor for more information about available concentrations and requirements.

- Algorithms and Complexity
- Computational Biology
- Computer Graphics
- Computer Systems
- Human-Computer Interaction
- Language Technologies
- Machine Learning
- Principles of Programming Languages
- Robotics
- Security and Privacy
- Software Engineering

Algorithms and Complexity Concentration

This concentration is available to SCS students only.

Ryan O'Donnell, *Concentration Director*
Location: GHC 7213

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The goal of the Algorithms and Complexity concentration is to give SCS students a deep background in the theory of computation as it relates to algorithms and computational complexity. The expectation is that students who complete this concentration will have the background to pursue topics at the PhD level at any top program in the country. Furthermore we expect the reasoning skills gained as part of this concentration could be a significant help in a wide variety of positions in industry.

The concentration is designed to be reasonably flexible covering a wide area of topics within the area of algorithms and complexity. This includes central topics within the area such as complexity theory, and algorithms, but also includes theory as used in areas such as Computational Geometry, Graph Theory, Cryptography, Machine Learning, Algorithms for Large Data, Error Correcting Codes, and Parallel Algorithms.

Common themes of all courses covered by the concentration are the following:

- Clearly defined formalisms of the subject matter.
- A substantial component involving rigorous mathematical analysis, including proofs.
- Abstracting away from specific applications to a more general context.
- Relating algorithms and/or complexity of computation to a variety of complexity measures such as time, space, communication, or information content.

Any given course does not have to exclusively cover these themes and can, for example, also cover experimental aspects of algorithms, or examples applied to quite specific applications.

Learning Objectives

We do not expect students to have high proficiency in all the examples listed, but to gain at least some proficiency from each category.

- The ability to take a loosely defined problem and clearly pose it as a well defined problem specification.
- The understanding of several advanced algorithms beyond what is covered in the core.
- The appreciation a variety of models for bounding resources, such as information theory, space complexity, parallel complexity, communication complexity, proof complexity, query complexity, and hardness of approximation.
- The ability to understand and apply a variety of advanced algorithmic techniques and proof techniques, such as Lovasz Local Lemma, Johnson Lindenstrauss, Chernoff Bounds, sparsification, expanders, probabilistic method, regret bounds, spectral graph theory, fixed parameter tractability and semi-indefinite programming.
- The ability to recognize flaws in ill-formed proofs.
- The ability to formulate new questions about the field.

Prerequisites

The following courses must be completed before the concentration can be completed:

| | | |
|--------|--|----|
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |
| 15-259 | Probability and Computing | 12 |
| | or 21-325 Probability | |
| | or 36-218 Probability Theory for Computer Scientists | |
| 15-451 | Algorithm Design and Analysis | 12 |

It is expected that all students will start the concentration after having finished all but 15-451.

Course Requirements

The curriculum consists of one required course and at least three elective courses. The three elective courses must sum to at least 30 units. The elective courses will vary from year to year.

Required:

| | | |
|--------|---------------------------------|---|
| 15-455 | Undergraduate Complexity Theory | 9 |
|--------|---------------------------------|---|

Electives (at least three courses with a total of 30 units or more):

| | | |
|--|------------------------------------|----|
| 15-354 | Computational Discrete Mathematics | 12 |
| 15-356 | Introduction to Cryptography | 12 |
| 15-458 | Discrete Differential Geometry | 12 |
| 15-459 | Undergraduate Quantum Computation | 9 |
| 15-751 | A Theorist's Toolkit | 12 |
| 21-301 | Combinatorics | 9 |
| 21-484 | Graph Theory | 9 |
| Special permission required: | | |
| 47-834 | Linear Programming | 6 |
| 47-835 | Network Optimization I | 6 |
| 47-836 | Network Optimization II | 6 |
| Other graduate-level courses as approved by the concentration director | | |

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

The choice of available elective courses will be posted prior to registration each semester.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any Major, Minor, or other concentration the student is pursuing.

Advising and Management

Courses in the list of electives will be approved by the director on a yearly basis under consultation of the algorithms and complexity group (to help evaluate the relevance of the courses) and the CS Program Director (to help flag any logistical issues). Any special requests by a student for counting a course out of the list, will go to the director. The director will also approve any research units.

Students interested in this concentration should contact the concentration director for an initial advising consultation.

Computational Biology Concentration

This concentration is available to SCS students only.

Phillip Compeau, *Concentration Director*
Location: GHC 7403

Tara Seman, *Concentration Coordinator*
Location: GHC 7414

The general goal of the Computational Biology Concentration is to provide foundational coursework in computational biology that will allow undergraduate students in the Carnegie Mellon University School of Computer Science to start building a skillset useful for understanding many of the modern technologies developed by researchers as well as companies in the biotech and biomedical arenas.

This concentration consists of four core courses providing breadth in computational biology across laboratory methods, machine learning, genomics, and modeling of biological systems, as well as one elective that allows students to complete depth coursework in an area of interest, including undergraduate research.

Learning Objectives

Students will, by way of completing this concentration:

- model biological systems at the molecular and cellular levels using a variety of approaches;
- generate their own high throughput molecular biology data in a laboratory setting, and apply computational techniques to analyze the data they generate;
- transform hazy biological problems involving genomic data into well-defined computational problems, design algorithms to solve these problems, and adapt them to biological data;
- explore additional coursework of interest in genomics, biological research automation, biological image analysis, or computational biology research.

This concentration also provides students completing a computational degree other than the major in computational biology (<http://www.cbd.cmu.edu/education/bs-in-computational-biology/>) with the opportunity to make a transition toward a career in computational biology. We have compiled information on over 250 companies working on computational biology into a unique web resource for students both inside and outside of Carnegie Mellon (<http://careers.cbd.cmu.edu> (<http://careers.cbd.cmu.edu/>)). These companies work on diverse topics from the automation of biological research to drug discovery to wearable medical devices to genetic diagnostics. Increasingly, when we interact with these companies, they want computationally minded candidates with as much knowledge of standard approaches in computational biology as possible.

Prerequisites

Note that not all of the prerequisites below are required to take every course in this concentration (for example, 02-251 does not have any of the pre-requisites below), but these courses are required to complete all of the required coursework and should be completed early within this concentration.

| | | |
|--------|--|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |

| | | |
|--------|--|----|
| 21-241 | Matrices and Linear Transformations | 11 |
| 36-218 | Probability Theory for Computer Scientists | 9 |

Further, the following two courses are not technically required as prerequisites to the courses in this concentration, but they are strongly suggested prerequisites because they provide students with helpful surveys of fundamental topics in biology and computational biology.

| | | |
|-----------|--------------------------------------|----|
| 02-251 | Great Ideas in Computational Biology | 12 |
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 | Modern Biology | |

Requirements

Five courses in total are required for this concentration. The following four courses are required as part of a central core of coursework; they consist of three computational biology courses as well as an introductory machine learning course, which today is fundamental for even an introductory understanding of the field.

| | | Units |
|--------|--|-------|
| 02-261 | Quantitative Cell and Molecular Biology Laboratory (03-343, Experimental Techniques in Molecular Biology, may be taken if 02-261 is not offered) | Var. |
| 02-510 | Computational Genomics | 12 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |

In addition to these four courses above, one elective course is required. Any 02-listed (Computational Biology Department) undergraduate course of at least 9 units at the 300-level or above may satisfy this requirement; graduate courses may be applied to this category with permission. The Computational Biology Department is growing quickly, but at the time of writing, the courses that are regularly offered by the department that would satisfy this requirement are the following:

| | | |
|--------|---|------|
| 02-317 | Algorithms in Nature | 9 |
| 02-319 | Genomics and Epigenetics of the Brain | 9 |
| 02-425 | Computational Methods for Proteogenomics and Metabolomics | 9 |
| 02-450 | Automation of Scientific Research | 9 |
| 02-499 | Independent Study in Computational Biology | Var. |
| 02-500 | Undergraduate Research in Computational Biology (03-441/03-541 may be taken if 02-500 is not offered) | Var. |
| 02-514 | String Algorithms | 12 |
| 02-515 | Advanced Topics in Computational Genomics | 12 |
| 02-518 | Computational Medicine | 12 |

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as the elective course for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

At most two courses can double count with all program requirements for majors, minors and other concentrations being pursued by the student. Courses used as free electives for a major are not considered double counted.

Accordingly, this concentration is expressly closed to majors and additional majors in computational biology.

CS and AI majors completing this concentration are encouraged to double-count 10-315 as well as 02-261 as their lab science course. Suggested prerequisites 03-151 and 02-251 also count as requirements for these degrees (as a Science & Engineering course and CS Domains course, respectively).

Advising and Management

The day-to-day management of this concentration (including declaration of the concentration, exception requests, overseeing student audits, advising, etc.) is handled by Phillip Compeau, Assistant Department Head in the Computational Biology Department. Administrative support for the concentration is provided by Samantha Mudrinich. Curricular

organization and annual review will be managed by the Computational Biology Undergraduate Review Committee.

SCS students interested in this concentration should set up an appointment with Phillip Compeau for a brief interview.

Computer Graphics Concentration

This concentration is available to SCS students only.

Nancy Pollard, *Concentration Director*
Location: EDSH 227

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The SCS Computer Graphics Concentration provides an opportunity for SCS undergraduate students at Carnegie Mellon to learn Computer Graphics foundations and specialties from a variety of application and research areas. Students gain a broad view of Computer Graphics in an introductory course and in-depth experience from a choice of topic areas, including the option of independent research. Courses include computational photography, computer games, computer animation, computational geometry, and physics-based rendering. This concentration provides an excellent introduction to the area for students considering industry and the opportunity for research experience for those considering graduate study.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- Create geometric representations for objects and natural phenomena.
- Develop software systems that work with these representations to capture, manipulate, and create artistic and real-world scenes.
- Discuss the pros and cons of alternative models of light transport.
- Develop software systems that utilize these models to create graphical images.
- State the key principles of animation and computer game development.
- Work with kinematic and physically simulated representations of motion to create animations of characters and natural phenomena.
- List key features of camera design, including for the modern camera.
- Work with images and video to perform common operations or generate new creative content.
- Execute common mathematical operations of computer graphics, including geometric transformations, projections, sampling algorithms, modeling of physical processes, optimization, and behavior-based modeling.
- Produce event-driven programs of moderate to large size with constantly evolving graphical / visual display.
- Sketch the layout of a typical massively parallel graphics processing unit (GPU).
- Write software to program the GPU for real-time graphics tasks.

Prerequisites

The following courses must be completed before the concentration can be completed:

| | | |
|--------|-------------------------------------|----|
| 15-213 | Introduction to Computer Systems | 12 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-259 | Calculus in Three Dimensions | 10 |

It is expected that all students will start the concentration after having finished all but 15-451.

Course Requirements

The curriculum consists of one required course and at least three elective courses. The three elective courses must sum to at least 30 units. The elective courses will vary from year to year.

Required:

| | | |
|--------|-------------------|----|
| 15-462 | Computer Graphics | 12 |
|--------|-------------------|----|

Electives (at least three courses with a total of 30 units or more):

| | | |
|--------|--|----|
| 15-365 | Experimental Animation | 12 |
| 15-418 | Parallel Computer Architecture and Programming | 12 |

| | | |
|------------------------------|---|----|
| 15-456 | Computational Geometry | 9 |
| 15-458 | Discrete Differential Geometry | 12 |
| 15-463 | Computational Photography | 12 |
| 15-464 | Technical Animation | 12 |
| 15-465 | Animation Art and Technology | 12 |
| 15-466 | Computer Game Programming | 12 |
| 15-468 | Physics-Based Rendering | 12 |
| 15-469 | Special Topic: Visual Computing Systems | 12 |
| Special permission required: | | |
| 16-726 | Learning-based Image Synthesis | 12 |
| 16-823 | Physics-based Methods in Vision (Appearance Modeling) | 12 |

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

RELATION TO OTHER PROGRAMS

The Computer Graphics Concentration overlaps slightly in course offerings of the IDEATE minors in Game Design and Animation and Special Effects, and interested students may also want to investigate these minors. What distinguishes the Computer Graphics Concentration is its focus on the fundamental theory, algorithms, and systems that are relevant to graphics. As such, this is an ideal choice for students who wish to get more in-depth, e.g., in preparation for graduate study or a career in Computer Graphics research.

Other courses to be aware of include:

- 21-344 Numerical Linear Algebra
- 10-725 Convex Optimization

Although they are not a core part of the concentration, these can be valuable courses for additional preparation for the mathematics that runs throughout computer graphics, as well as to prepare for future research and exploration in the field.

Double Counting

At most one course taken for the concentration may be double counted towards any major, minor or other concentration being pursued by the student. No other double counting is permitted.

Computer Systems Concentration

This concentration is available to SCS students only.

Brian Railing, *Concentration Director and Advisor*
Location: GHC 6005

Amy Weis, *Concentration Coordinator*
Location: GHC 4115

The goal of the Computer Systems concentration is to give students a broad background in the practical understanding of designing and building systems. Students who complete this concentration are expected to be able to both pursue topics at the Ph.D. level at top programs, as well as industry work, either applying these concepts or directly working within the areas of kernel development, compiler improvements, designing distributed systems, et cetera.

The concentration is designed to be flexible in covering the wide area of systems topics. Two courses from the Computer Science major's "systems" constrained elective are required (List A below). The other courses come from a larger list of related courses (List B below). A limited amount of research credit can count toward the requirements.

Typically, systems courses include three aspects:

- A systems course educates students about how a class of computer systems works, both at a conceptual level and in practice. This includes the study of concrete problems faced in building a particular class of systems and successful solutions to these problems.
- Systems courses address how properties of modern hardware (e.g., processors, net-works, storage hierarchies) influence the design and implementation of a class of soft-ware systems. This typically includes

reasoning about concurrency, and understanding and measuring performance.

- To solidify the key systems organization principles, there is a significant project/system implementation aspect to the course, both to reinforce understanding of how these systems work, and to learn system building skills (i.e., not just programming, but also design, debugging, testing, etc.). The size of the programming tasks is course dependent, but a significant fraction of the course grade (e.g., at least 40%) is derived from project work.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- Students will be able to design, develop and deploy large computer systems and justify their design decisions.
- Students will synthesize the interaction and tradeoffs between different layers and components in computer systems.
- Students will demonstrate debugging expertise on complex and diverse bugs and issues during software development.
- Students will recognize diverse granularities of parallelism, apply them toward solving problems, and implement solutions that achieve correct execution while accounting for reliability, fault tolerance, performance, security, and scalability.

Prerequisites

All students will start the concentration after having finished 15-213 Introduction to Computer Systems (or its cross-listed equivalents) with a C or better, as 15-213 is a prerequisite either directly or indirectly for all courses in the concentration.

Course Requirements

The curriculum will consist of at least four courses: two courses from List A and at least two elective courses from List B. The courses taken from list A and B must sum to at least 51 units. The courses in List A will follow the Systems constrained elective list as part of the degree requirements for a B.S. in Computer Science. The elective courses on List B may vary from year to year, with a plan to review these requirements every three years.

List A (select two):

| | | |
|--------|--|----|
| 15-410 | Operating System Design and Implementation | 15 |
| 15-411 | Compiler Design | 15 |
| 15-418 | Parallel Computer Architecture and Programming | 12 |
| 15-440 | Distributed Systems | 12 |
| 15-441 | Networking and the Internet | 12 |
| 15-445 | Database Systems | 12 |

List B (select at least two):

| | | |
|-------------------------------|--|------|
| Anything from List A, plus... | | |
| 15-319 | Cloud Computing | 12 |
| 15-330 | Introduction to Computer Security | 12 |
| 15-346 | Computer Architecture: Design and Simulation | 12 |
| 15-348 | Embedded Systems | 9 |
| 15-412 | Operating System Practicum | Var. |
| 15-415 | Database Applications | 12 |
| 17-422 | Building User-Focused Sensing Systems | 12 |
| 18-341 | Logic Design and Verification | 12 |
| 18-344 | Computer Systems and the Hardware-Software Interface | 12 |
| 18-349 | Introduction to Embedded Systems | 12 |
| 18-447 | Introduction to Computer Architecture | 12 |

Special permission required for:

| | | |
|--------|--------------------------|----|
| 15-719 | Advanced Cloud Computing | 12 |
|--------|--------------------------|----|

Other graduate-level courses in CSD as approved by the concentration director

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration in list B. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

The concentration will require that 3 courses (at least 27 units) are not double counted with any other requirements of any major, minor, or other concentration.

Advising and Management

The courses on the list of electives will be reviewed yearly by the concentration advisor through consultation with the Systems group (to help evaluate the relevance of the courses) and the CS Program Director (to help flag any logistical issues). Any special requests by a student for counting a course outside of the list will go to the concentration advisor. The concentration advisor will also approve any research units.

Students interested in this concentration should set up an initial advising consultation with the concentration advisor.

Human-Computer Interaction Concentration

This concentration is available to SCS students only.

Haiyi Zhu, *Undergraduate Director*
Email: haiyiz@andrew.cmu.edu

Amelia Baisley, *Concentration Manager*
Location: Newell-Simon Hall 3526B

In this concentration, students learn techniques, processes, principles, and theory of Human-Computer Interaction (HCI). This interdisciplinary field aims at understanding how interactions with digital technologies and services can augment what humans do. It also aims at understanding what design, prototyping, and evaluation processes lead to innovative digital technologies and services that fulfill human needs. The concentration enhances what is learned in the SCS majors by addressing how digital products and services can be designed and evaluated so they benefit individuals, small groups, organizations, larger networks, and societies. It is synergistic with SCS majors in that envisioning, designing, and implementing innovative digital interactions benefit from superior technical skill. The concentration consists of 5 courses (2 required courses and 3 electives).

The concentration helps prepare students for jobs as technically-skilled specialists in design and development of interactive systems. The concentration will give students a broader perspective on how technologies impact humans, which may help them move faster into product management positions. It also lays a foundation for graduate study in the field of Human-Computer Interaction.

Learning Objectives

Students will learn skills and methods for:

- Eliciting and understanding human objectives, preferences, and needs through qualitative and quantitative methods for data collection and analysis
- Generating and imagining possible solutions and design concepts that involve human/technology partnerships
- Basic visual design, including typography, grids, color and the use of images
- Design of interactive systems, experiences, and technologies
- Developing and evaluating interactive prototypes as a way of iteratively refining designs
- Evaluating interactive technologies to assess and improve their functioning through data-driven redesign, including discount and empirical evaluation methods

Students will also learn about:

- Digital technologies, including, possibly, web and mobile platforms, conversational technologies, wearable computing, gadgets, digital fabrication, virtual reality and mixed reality
- Human psychology, regarding individuals, groups, organizations, societies, and cultures, as it relates to interactions with digital products and services

Prerequisites

For this concentration, students should have completed the following courses prior to starting the concentration:

| | | |
|--------|--------------------------------------|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |

Course Requirements

The following requirements are for students entering Fall 2023.

Students in an SCS major wanting to complete a concentration in HCI must complete 5 courses, namely, 2 required courses and 3 electives.

Required courses (2 courses)

| | | |
|--------|-----------------------------------|----|
| 05-391 | Designing Human Centered Software | 12 |
| 05-360 | Interaction Design Fundamentals | 12 |

Electives (3 courses)

1. At least one of the electives must have strong technical content and must be selected from the following list:

| | | |
|--------|---|----|
| 05-318 | Human AI Interaction | 12 |
| 05-333 | Gadgets, Sensors and Activity Recognition in HCI | 12 |
| 05-434 | Machine Learning in Practice | 12 |
| 05-499 | Special Topics in HCI | 12 |
| 05-839 | Interactive Data Science | 12 |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 11-411 | Natural Language Processing | 12 |
| 15-237 | Special Topic: Cross-Platform Mobile Web Apps | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-365 | Experimental Animation | 12 |
| 15-388 | Practical Data Science | 9 |
| 15-462 | Computer Graphics | 12 |
| 15-464 | Technical Animation | 12 |
| 15-466 | Computer Game Programming | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-467 | Human Robot Interaction | 12 |
| 17-422 | Building User-Focused Sensing Systems | 12 |
| 17-428 | Machine Learning and Sensing | 12 |
| 17-437 | Web Application Development | 12 |
| 17-537 | Artificial Intelligence Methods for Social Good | 9 |

Other courses as approved by the concentration director

2. At least one of the electives must have strong design content and must be selected from the following list:

| | | |
|--------|--|----|
| 05-361 | Advanced Interaction Design | 12 |
| 05-291 | Learning Media Design | 12 |
| 05-315 | Persuasive Design | 12 |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-418 | Design Educational Games | 12 |
| 05-452 | Service Design | 12 |
| 05-470 | Digital Service Innovation | 12 |

*Some (but not all) special topics classes (05-499) might also count towards the design elective requirement. Please consult with an HCI undergraduate advisor.

3. The remaining elective must be a course in HCI offered by the Human-Computer Interaction Institute, meaning it has a 05 number, or is included in the pre-approved list of electives maintained on the HCII website: <https://hcii.cmu.edu/academics/hci-undergrad/electives> (<https://hcii.cmu.edu/academics/hci-undergrad/electives/>)

Students can apply one semester of a senior thesis or research-based independent study (05-589) in a topic related to this concentration, as approved by the concentration director/advisor, as an elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units towards the concentration and can count for at most one elective.

Double Counting

At most 2 courses can be double counted with any major, minor or other concentration being pursued by the student.

ADVISING AND MANAGEMENT

Management will fall on the HCII Undergraduate Director and the HCII Academic Program Coordinator. The requirements for the courses will be reviewed annually by the HCII Curriculum Committee, in consultation with the URC.

Students in the HCI concentration will be advised by the HCII Undergraduate Director and/or the HCII Academic Program Coordinator, who also oversee and direct the HCI additional major and the HCI minor.

SCS Students interested in this concentration should contact the HCII Academic Program Coordinator for an initial advising consultation.

Language Technologies

This concentration is available to SCS Students only.

Carolyn P Rose (cp3a@andrew.cmu.edu), Concentration Director/Advisor
Location: 5415 Gates Hillman Center

Introduction

Human language technologies have become an increasingly central component of computer science. Information retrieval, machine translation and speech technology are used daily by the general public, while text mining, natural language processing and language-based tutoring are common within more specialized professional or educational environments. The Language Technologies Institute prepares students for this world by offering a concentration for SCS majors that gives these students the opportunity to not only learn about language technologies, but to also apply that knowledge through a directed project.

Learning Objectives

Students should be able to...

- Apply the principles of phonetics, morphology, morphosyntax, syntactic formalisms, discourse analysis and pragmatics and sociolinguistics to analyze, describe and discuss languages that they do not normally speak.
- Implement algorithms for organizing and searching large text collections through data mining or building text-based search engines.
- Process natural language input computationally to create automated, intelligent systems to perform language translation, implement question answering, build conversation agents, and query databases using natural interfaces.
- Develop systems that recognize human speech and synthesize human speech.
- Describe the limitations of speech and language analysis systems to pick the most appropriate tools and techniques for the given problem.
- Apply principles in language technologies to a research problem or study to advance the state of the art in this field.

Course Requirements

The Language Technologies Concentration requires that SCS students complete one core course and their choice of three elective courses of at least 9 units each. The electives can be chosen from a specific set of stand-alone courses. In addition to the four courses, students are required to do an undergraduate research project for at least 9 units to complete their concentration.

Core Course (12 units)

Students must take the core course below:

| | | |
|--------|--|----|
| 11-324 | Human Language for Artificial Intelligence | 12 |
|--------|--|----|

Electives (minimum of 27 units)

Students must complete 3 electives from the following list of courses for a minimum of 27 units.

| | | |
|--------|---|----|
| 11-411 | Natural Language Processing | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-442 | Search Engines | 9 |
| 11-492 | Speech Processing | 12 |
| 11-344 | Machine Learning in Practice | 12 |
| 11-711 | Advanced Natural Language Processing | 12 |
| 11-731 | Machine Translation and Sequence-to-Sequence Models | 12 |
| 11-737 | Multilingual Natural Language Processing. | 12 |
| 11-747 | Neural Networks for NLP | 12 |
| 11-751 | Speech Recognition and Understanding | 12 |
| 11-761 | Language and Statistics | 12 |

| | | |
|--------|--------------------------------|----|
| 11-776 | Multimodal Affective Computing | 12 |
| 80-180 | Nature of Language | 9 |

Research or Additional Elective (MINIMUM OF 9 UNITS)

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective. Students who opt not to do research may take an additional elective from the list above.

Prerequisites

The following courses are expected to be completed before the Core courses in the ML Concentration:

- CS background:
 - 15-122 Principles of Imperative Computation
 - 15-150 Principles of Functional Programming
- One year of calculus: 21-120 Differential and Integral Calculus and 21-122 Integration and Approximation or equivalent
- Matrix Algebra: 21-241 Matrices and Linear Transformations or 21-242 Matrix Theory
- Probability: 15-259 Probability and Computing or 21-325 Probability or 36-218 Probability Theory for Computer Scientists or 36-225 Introduction to Probability Theory

Double Counting

Courses being used to satisfy the requirements for the Language Technologies Concentration may not be counted towards another minor or concentration. 11-324 Human Language for Artificial Intelligence and 80-180 Nature of Language are the only courses that may be double counted with any other major or minor. All other courses used toward the concentration cannot be counted toward any requirement other than free electives.

Advising

The Language Technologies Concentration Advisor will assist students in selecting appropriate courses and reviewing completion of concentration requirements. Students working towards this concentration are welcome to reach out to the Director at any time for meetings to discuss the program, research directions, and career path questions.

Management

A student working towards the Language Technologies Concentration will select a Language Technologies faculty member as an Advisor with the assistance of the Director. There is also a Language Technologies Concentration Program Coordinator who is a staff member in the Language Technologies Institute. Curriculum changes to this concentration will be reviewed by the Undergraduate Review Committee for approval.

Machine Learning Concentration

This concentration is available to SCS students only.

Matt Gormley, *Concentration Director/Advisor*
Location: GHC 8103

Laura Winter, *Concentration Coordinator*
Location: GHC 8001

ml-concentration@cs.cmu.edu

Machine learning and statistical methods are increasingly used in many application areas including natural language processing, speech, vision, robotics, and computational biology. The Concentration in Machine Learning allows undergraduates to learn about the core principles of this field. The Concentration requires five courses (two core courses and three electives) from the School of Computer Science (SCS) and the Department of Statistics & Data Science. The electives primarily focus on core machine learning skills that could be broadly applicable to either industry or graduate work. A CS Senior Honors Thesis or two semesters of Senior Research may be used to satisfy part of the electives requirement, which could provide excellent research experience for students interested in pursuing a PhD.

Learning Objectives

Upon completion of this concentration, students should be able to:

- Formulate real-world problems involving data such that they can be solved by machine learning
- Implement and analyze existing learning algorithms
- Employ probability, statistics, calculus, linear algebra, and optimization in order to develop new predictive models or learning methods
- Select and apply an appropriate supervised learning algorithm for problems of different kinds, including classification, regression, structured prediction, clustering, and representation learning
- Describe the formal properties of models and algorithms for learning and explain the practical implications of those results
- Compare and contrast different paradigms for learning

Prerequisites

The following courses are expected to be completed before the Core courses in the ML Concentration:

| | | |
|--------|--|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| | or 21-127 Concepts of Mathematics | |
| | or 21-128 Mathematical Concepts and Proofs | |
| 36-235 | Probability and Statistical Inference I | 9 |
| | or 36-218 Probability Theory for Computer Scientists | |
| | or 36-219 Probability Theory and Random Processes | |
| | or 36-225 Introduction to Probability Theory | |
| | or 15-259 Probability and Computing | |
| | or 21-235 Mathematical Studies I | |

Course Requirements

The ML Concentration requires that students complete two core courses and their choice of three elective courses of at least 9 units each. The electives can be through a combination of coursework in Machine Learning and optionally senior research.

Core - 2 Courses:

Students must take two core courses, each being at least 9 units:

| | | |
|--------------|---|----|
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| Plus one of: | | |
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| | or 10-405 Machine Learning with Large Datasets (Undergraduate) | |
| | or 10-414 Deep Learning Systems: Algorithms and Implementation | |
| | or 10-417 Intermediate Deep Learning | |
| | or 10-418 Machine Learning for Structured Data | |
| | or 10-422 Foundations of Learning, Game Theory, and Their Connections | |

Electives - 3 Courses:

Students need to take three courses from the following list, each being at least 9 units. Students may substitute one of these courses with one semester of an SCS Senior Honors Thesis or equivalent senior research credit.

| | | |
|--------|---|----|
| 10-403 | Deep Reinforcement Learning & Control | 12 |
| | or 10-703 Deep Reinforcement Learning & Control | |
| 10-405 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| | or 10-605 Machine Learning with Large Datasets | |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| | or 11-485 Introduction to Deep Learning | |
| | or 10-707 Advanced Deep Learning | |
| 10-418 | Machine Learning for Structured Data | 12 |
| | or 10-708 Probabilistic Graphical Models | |
| 10-422 | Foundations of Learning, Game Theory, and Their Connections | 12 |
| 10-425 | Introduction to Convex Optimization | 12 |
| | or 10-725 Convex Optimization | |
| 10-613 | Machine Learning Ethics and Society | 12 |
| 10-777 | Historical Advances in Machine Learning | 12 |
| 36-401 | Modern Regression | 9 |

Important Notes:

- To avoid excessive overlap in covered material, at most one of the core Deep Learning courses may be used to fulfill concentration course requirements: 10-417, 10-617, 11-485, 10-707. In general, students are discouraged from taking more than one of these.
- 15-281 Artificial Intelligence: Representation and Problem Solving covers several topics (i.e. reinforcement learning and Bayesian networks) that are complementary to 10-315. While not part of the ML Concentration curriculum, this course is also one to consider.
- Students should note that some of these elective courses (those at the 600-level and higher) are primarily aimed at graduate students, and so should make sure that they are adequately prepared for them before enrolling. Graduate-level cross-listings of these courses can also be used for the ML Concentration, if the student is adequately prepared for the more advanced version and the home department approves the student's registration.
- Please be aware that not all graduate-level courses in the Machine Learning Department may be used as electives. In particular, 10-606/10-607 Computational Foundations for Machine Learning may not be used as electives for the Machine Learning Concentration.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

SCS Senior Honors Thesis

The SCS Senior Honors Thesis consists of 36 units of academic credit for this work. Up to 12 units may be counted towards the ML Concentration. Students must consult with the Computer Science Department for information about the SCS Senior Honors Thesis. Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration.

Senior Research

Senior Research consists of 2 semesters of 10-500 Senior Research Project, totaling 24 units. Up to 12 units may be counted towards the ML Concentration.

The research must be a year-long senior project, supervised or co-supervised by a Machine Learning Core Faculty member. It is almost always conducted as two semester-long projects, and must be done in senior year. Some samples of available Machine Learning Senior Projects are available on the Machine Learning Department webpage. Interested students should contact the faculty they wish to advise them to discuss the research project, before the semester in which research will take place.

Once both student and advisor agree upon a project, the student should submit a one-page research proposal to the Machine Learning Concentration Director to confirm that the project will count for the Machine Learning Concentration. The student will present the work and submit a year-end write-up to the Concentration Director at the end of Senior year.

Double Counting

At least 3 courses (each being at least 9 units) must be used for only the Machine Learning Concentration, not for any other major, minor, or concentration. (These double counting restrictions apply specifically to the Core Courses and the Electives. Prerequisites may be counted towards other majors, minors, and concentrations and do not count towards the 3 courses that must be used for only the Machine Learning Concentration.)

Advising and Management

The ML Concentration Director will hold advising office hours leading up to registration week each semester. In addition, the ML Concentration Program Coordinator will hold regular office hours to address general questions. All office hours will be detailed on the ML Concentration website.

SCS Students interested in pursuing this concentration should contact Matt Gormley for an initial advising consultation.

Principles of Programming Languages Concentration

This concentration is available to SCS students only.

Robert Harper, *Concentration Director and Advisor*

Location: GHC 9229

Amy Weis, *Concentration Coordinator*

Location: GHC 4115

Programming languages play a central role in computer science. All programs are written in a language, and it is obvious that some are better than others, at least for some purposes. The constant demand for new languages reflects the changing demands for constructing reliable and maintainable software systems. Academic research in programming language principles has led to numerous advances in language design, language implementation, and program verification intended to meet these changing expectations through the development of a rigorous theory of programming languages.

Carnegie Mellon is a recognized leader in programming languages, characterized by a strong emphasis on the centrality of type theory, a consolidation of ideas in mathematical semantics, programming logics, and programming language design and implementation. The purpose of the PoPL concentration is to teach the comprehensive view of the field that has been developed here over many decades. Type theory teaches how to define a language, and how to show that it is well-defined, free of internal contradictions. It teaches the mathematical foundations for abstraction and modularity, concepts that are fundamental to building maintainable systems. It teaches how to use a rigorous language definition as the basis for building a compiler that correctly implements the definition, and provides the tools necessary to achieve it. It teaches the logical foundations of program development, how to precisely specify the intended behavior of a program, and how to use machine tools to verify that a program meets those expectations. It gives precise meaning to language concepts, relating them to one another, and distinguishing concepts that are often confused or conflated. It teaches how to specify and verify the resource usage of a program (such as its sequential and parallel time and space complexity) without resorting to a model of how it is implemented on a machine; it supports using actual code, rather than pseudo-code, for defining and analyzing algorithms.

The PoPL concentration is of value to a broad range of students. For the practically minded it will provide the foundation for structuring and validating programs, using type systems or more advanced forms of specification. For the theoretically minded it will provide the foundation for understanding the close relationship between specification and programs on one hand and mathematical conjecture and proof on the other. The elegance of the PoPL lies in their unification of these two perspectives: the theory applies directly to the practice, and the practice informs the theory.

Learning Objectives

The PoPL concentration is characterized by a collection of learning outcomes that it seeks to achieve. These may be summarized by the knowledge that students may expect to gain by concentrating in the area. By their choice of electives each student will choose an emphasis within the area; the required courses ensure that this includes at least the first five objectives:

- Specify the concrete and abstract syntax of a programming language, including a precise specification of the binding and scope of declarations.
- Define the static semantics (compile-time constraints) of a programming language using typing judgments, and how to state and prove that it properly defined.
- Define the dynamics semantics (run-time behavior) of a language using operational and denotational methods.
- Verify rigorously that the statics and dynamics of a language are coherent, a property commonly called type safety.
- Understand the propositions-as-types principle, which relates programs to proofs and specifications to theorems, and know how to apply it in language design and program verification.
- Formulate type and assertion languages for specifying the behavior of a program, and how to verify that a program satisfies such a specification.
- Specify the cost (sequential and parallel time and space complexity) for a program written in a precisely defined language, and how to verify that a given program meets stated cost bounds.
- Use software tools to verify both the properties of languages and the specifications of programs written in well-defined languages.
- Use the static and dynamic semantics of a language to derive a compiler for it that complies with these definitions, and how to use types and verification tools to ensure compiler correctness.
- Relate a language definition to its implementation, both in terms of the run-time structures required, but also to validate abstract cost measures in an implementation.

REQUIREMENTS

This concentration requires two courses along with two additional electives.

Required Courses (complete all of the following):

| | | |
|--------|--------------------------------------|----|
| 15-312 | Foundations of Programming Languages | 12 |
| 15-317 | Constructive Logic | 9 |

Electives (complete two of the following):

| | | |
|--------|---|----|
| 15-314 | Programming Language Semantics | 12 |
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-414 | Bug Catching: Automated Program Verification | 9 |
| 15-417 | HOT Compilation | 12 |
| 15-424 | Logical Foundations of Cyber-Physical Systems | 12 |

Any graduate-level Programming Languages course(s), with prior permission of the concentration advisor and the course instructor(s).

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research should be supervised by a member of the Principles of Programming faculty in the Computer Science Department. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Transfer of credit for courses taken outside of Carnegie Mellon University toward this concentration will not be allowed.

Double Counting

Either 15-312 or 15-317 (but not both) may be double counted towards any major, minor or other concentration being pursued by the student. No other double counting is permitted.

Advising and Management

Participation in this concentration is supervised by the concentration coordinator in cooperation with the students academic advisor, course instructors, and, as appropriate, thesis supervisor. The current advisor is Robert Harper. Content for this concentration will be reviewed yearly by the Principles of Programming faculty in the Computer Science Department.

Students interested in pursuing this concentration should contact Robert Harper for an initial advising consultation.

Robotics Concentration

This concentration is available to SCS students only.

Cameron Riviere, *Concentration Director/Advisor*
Location: NSH 3205

Barbara ("B.J.") Fecich, *Concentration Administrator*

The SCS Robotics Concentration provides an opportunity for SCS undergraduate students at Carnegie Mellon to learn the principles and practices of robotics through theoretical studies and hands-on experience with robots. Students initially learn the basics of robotics in an introductory robotics overview course. Additional required courses teach control systems and robotic kinematics. Students also choose from a wide selection of electives in mobile systems, machine learning, computer vision, cognition and cognitive science, or computer graphics. Students have a unique opportunity to undertake independent research projects, working under the guidance of Robotics Institute faculty members; this provides an excellent introduction to robotics practice, for those considering industry and research for those considering graduate studies.

Learning Objectives

Students completing this concentration will be able to demonstrate the following skills and learning:

- construct robots which are driven by a microcontroller through several projects, with each project reinforcing the basic principles of: vision, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensing
- apply feedback control theory to the development of robotic systems, including the principles of classical linear control theory, linear

state-space methods, nonlinear systems theory, and elementary control using computer learning techniques

- program a robot arm using the principles of kinematics and dynamics: transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and the basic equations of motion
- apply related fields of computing to the construction and testing of robotic solutions: machine learning, AI, graphics and computer vision, cognitive science and learning models, cyber-physical and embedded systems
- work effectively in a team include computer and mechanical engineers to solve challenging robotics problems

Prerequisites

The following courses are expected to be completed before the Core courses in the Robotics Concentration:

CS background:

| | | |
|--------|--------------------------------------|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-213 | Introduction to Computer Systems | 12 |

One year of calculus:

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |

Matrix Algebra (one of the following):

| | | |
|--------|-------------------------------------|----|
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-242 | Matrix Theory | 11 |

Probability (one of the following):

| | | |
|--------|--|----|
| 15-259 | Probability and Computing | 12 |
| 21-325 | Probability | 9 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

The probability course can be taken concurrently with the concentration requirements. Depending on specific electives chosen, additional prerequisites may be required (e.g. 21-259).

Course Requirements

The Robotics Concentration requires that students complete three core courses and their choice of two elective courses of at least 9 units each. The electives can be chosen from a specific set of stand-alone courses. Students can opt to do an undergraduate research project as one of their electives.

Required core courses (36 units)

| | | |
|---------------------------------|--|----|
| 16-311 | Introduction to Robotics | 12 |
| plus the following two courses: | | |
| 16-299 | Introduction to Feedback Control Systems | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |

Electives (minimum 18 units)

Students must complete 2 electives from the following list of courses for a minimum of 18 units. At least one of the two elective courses must be from the Robotics Institute (16-xxx). A maximum of 12 units of research (16-597) can be used toward this requirement.

| | | |
|--------|---|------|
| 16-264 | Humanoids | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-385 | Computer Vision | 12 |
| 16-421 | Vision Sensors | 12 |
| 16-423 | Designing Computer Vision Apps | 12 |
| 16-597 | Undergraduate Reading and Research | Var. |
| 10-315 | Introduction to Machine Learning (SCS Majors) | 12 |
| 11-344 | Machine Learning in Practice | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-348 | Embedded Systems | 9 |
| 15-424 | Logical Foundations of Cyber-Physical Systems | 12 |
| 15-462 | Computer Graphics | 12 |
| 15-463 | Computational Photography | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 85-370 | Perception | 9 |
| 85-395 | Applications of Cognitive Science | 9 |
| 85-412 | Cognitive Modeling | 9 |

| | | |
|--------|---|---|
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-426 | Learning in Humans and Machines | 9 |

Note: Graduate level Robotics courses may be used to meet the elective requirement with permission from the Concentration Advisor. Graduate level Mechanical Engineering and Electrical and Computer Engineering courses that are relevant to robotics may be used to meet the elective requirement with permission from the Concentration Advisor.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Double Counting

Courses being used to satisfy the requirements for the Robotics Concentration may not be counted towards another minor or concentration. A minimum of 27 units must be completed that is not double counted with any other program. This allows a maximum of 2 courses that can double count with other programs.

Advising and Management

The Robotics Concentration will always have a Robotics faculty member as its Advisor. There will also be a Robotics Concentration Administrator who will track progress for any SCS student pursuing this concentration. Curricular changes will be discussed with the Robotics Institute faculty and SCS academic deans.

Students interested in this concentration should set up an initial advising consultation with the Concentration Advisor to assess interest and preparation.

Security & Privacy Concentration (SCS)

This concentration is available to SCS students only. (ECE students should consult their department for an equivalent concentration.)

Lujo Bauer, *Concentration Director and Advisor*
Location: CIC 2203

In a world where data breaches and cyber-attacks are ever-present, the need for technologists who have a solid understanding of the principles that underlie strong security and privacy practices is greater than ever.

The Security & Privacy concentration is designed to expose students to the key facets of and concerns about computer security and privacy that drive practice, research, and legislation. On completing the curriculum, students will be well prepared to continue developing their interests in security or privacy through graduate study; to take jobs in security or privacy that will provide further training in applicable areas; and to be informed participants in public and other processes that shape how organizations and society develop to meet new challenges related to computer security or privacy.

Learning Objectives

After completing this concentration, students should:

- Understand how to reason about the adversary in computer systems.
- Be familiar with common security vulnerabilities, from buffer overflows and return oriented programming to cross-site scripting, and widely deployed defenses against these vulnerabilities.
- Be familiar with and understand how to apply the basic concepts in cryptography and secure system design and analysis.
- Understand the key properties of commonly used cryptographic primitives and properties commonly desired of cryptographic protocols.
- Be familiar with current and upcoming research directions in secure system design, software analysis, and cryptography.
- Be familiar with the breadth of concerns and topics relevant to computer security and privacy, ranging from technical topics to ethics, regulation, usability, and economics.
- Be familiar with the key concepts in privacy, ranging from conceptions of privacy to privacy algorithms to regulation and policy.

- Gain a more in-depth understanding of one “context” area: usable security and privacy, or policy.

Prerequisites

Students interested in pursuing this concentration should have the following courses completed before starting the concentration:

| | | |
|--------|---|----|
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Curriculum

A distinguishing feature of this field is the ubiquitous need to consider an adversary, and the resulting interplay between attack and defense that routinely advances both theory and practice. In order to understand widely-deployed defensive techniques and secure-by-design approaches, students must also understand the attacks that motivate them and the “adversarial mindset” that leads to new forms of attack. The curriculum is designed around this principle.

Students in the Security & Privacy concentration will take courses that cover the basic principles (*Introduction and Basics Course Area*), the underlying theory (*Theoretical Foundations Course Area*), and the practical application (*System Design Course Area*) of security and privacy. Additionally, they will be required to select a course which covers either usability or policy (*Context Course Area*). Finally, students will have the opportunity to dive deep on a particular security & privacy topic by completing an elective of their choosing (*Depth Course Area*).

Requirements (5 courses, minimum 48 units):

| | |
|--|-------|
| Introduction/Portal Entry course | Units |
| 15-330 Introduction to Computer Security | 12 |

Crosslisted courses allowed.

| | |
|---|-------|
| Theoretical Foundations course (choose one option): | Units |
| 15-356 Introduction to Cryptography | 12 |
| or both: | |
| 17-731 Foundations of Privacy | 12 |
| 18-733 Applied Cryptography | |

Crosslisted courses allowed.

| | |
|---|-------|
| System Design course (choose one): | Units |
| 15-316 Software Foundations of Security and Privacy | 9 |
| 18-335 Secure Software Systems | 12 |

| | |
|---|-------|
| Context Course (select one): | Units |
| 17-334 Usable Privacy and Security | 9 |
| or one of: | |
| 17-333 Privacy Policy, Law, and Technology | 9 |
| 17-731 Foundations of Privacy (not available if used for Theoretical Foundations requirement) | 12 |

| | |
|---|-------|
| Depth Course (complete one option below): | Units |
| Option 1: Complete an elective course from the below list of approved electives, at least 9 units | 9 |
| Option 2: Complete an additional course from the prior categories | 9 |
| Option 3: Complete at least 9 units of Independent Study - this option must be pre-approved by your primary advisor as well as the Concentration Director, and an appropriate faculty advisor and study plan submitted. | 9 |

Approved Elective List:

| | | |
|--------|--|----|
| 11-488 | Concepts in Digital Multimedia and Cyber Forensics | 12 |
| 14-795 | AI Applications in Information Security | |
| 14-828 | Browser Security | |
| 14-809 | Introduction to Cyber Intelligence | |
| 14-814 | Wireless Network Security | |
| 14-819 | Introduction to Software Reverse-Engineering | |
| 14-822 | Host-Based Forensics | |
| 14-823 | Network Forensics | |
| 14-829 | Mobile and IoT Security | |
| 15-435 | Foundations of Blockchains | 12 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | 9 |

| | | |
|--------|--------------------------------------|----|
| 17-735 | Engineering Privacy in Software | 12 |
| 17-880 | Algorithms for Private Data Analysis | 12 |
| 18-334 | Network Security | 12 |
| 18-632 | Introduction to Hardware Security | |
| 18-636 | Browser Security | |

Crosslisted courses allowed.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration (see option 3 above). This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective.

Anti-requisites

When two (or more) courses overlap significantly in the material they cover, only one can count toward the security and privacy concentration. An example pair is 15-316 Software Foundations of Security and Privacy and 18-335 Secure Software Systems. Another excluded pair is 15-356 Introduction to Cryptography and 18-733 Applied Cryptography. Other such anti-requisites may occur; please consult the concentration director when scheduling courses.

Excluded Courses

Some security and privacy courses may not be counted towards concentration requirements. These courses all serve specific important different purposes, but do not fit into the concentration as currently designed. For example, 17-331 is more suitable for students who are interested in a broader single-course introduction to information security, but has too much overlap with the concentration's required intro course to be able to count toward the concentration. For other excluded courses, please consult the concentration website.

Double Counting

Only two of the courses that are counted toward concentration requirements can also be counted towards core course requirements of other majors and minors being pursued by the student. SCS or ECE General Education Requirements are not included in this double-counting limit.

Advising and Management

The concentration is open to all undergraduates in the School of Computer Science. There is no formal admissions process. Students intending to pursue the concentration should contact the concentration coordinator to register their intention. Curriculum for the concentration will be reviewed by the coordinator annually in consultation with faculty in supporting departments.

Software Engineering Concentration**This concentration is available to SCS students only.**

Michael Hilton, *Concentration Director and Advisor*
Location: Wean Hall 5122

Effectively building modern software systems at scale requires not just programming skills, but also engineering skills. These skills include the ability to interact effectively with customers to gather the requirements for a system in a precise way; to develop a design that resolves competing quality attributes; to make tradeoffs among schedule, cost, features, and quality to maximize value to stakeholders; to work effectively with other engineers; and to assure the quality of the delivered software system. We hear regularly from industry that these skills are crucial to them, and that they are interested in students with a strong software engineering background.

Learning Objectives

The software engineering concentration is designed to teach the fundamental tools, techniques, and processes of software engineering. Through internships and a mentored project experience, students gain an understanding of the issues of scale and complexity that motivate software engineering tools and techniques. The core curriculum includes material both on engineering the software product and on the process, teamwork, and management skills that are essential to successful engineering. Graduates of the program should have the technical, process, and teamwork skills to be immediately productive in a mature engineering organization.

Prerequisites

SCS students should have completed the following courses before completing this concentration:

| | | |
|--------|--|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-151 | Mathematical Foundations for Computer Science | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 17-214 | Principles of Software Construction: Objects, Design, and Concurrency (This prerequisite exists to ensure software development experience, and may be waived if the student can show significant development experience. Please contact the Concentration Director to request this prerequisite be waived.) | 12 |

Course Requirements

Overall, the concentration requires five (5) courses and an internship. One of the five courses consists of a 6-credit course that serves as a writing workshop in which the student reflects upon and integrates the lessons of the internship.

Required Courses (complete all of the following):

| | | |
|--------|-------------------------------------|----|
| 17-313 | Foundations of Software Engineering | 12 |
| 17-413 | Software Engineering Practicum | 12 |

Electives (complete each category):

Domain-Independent Elective course or mini sequence focused on technical software engineering material (minimum 9 units required):

At least 9 units total.

| | | |
|--------|--|----|
| 15-316 | Software Foundations of Security and Privacy | 9 |
| 15-414 | Bug Catching: Automated Program Verification | 9 |
| 17-355 | Program Analysis | 12 |
| 17-356 | Software Engineering for Startups | 12 |
| 17-731 | Foundations of Privacy | 12 |
| 17-821 | Computer Simulation of Complex Socio-Technical Systems | 12 |

Or combine the following Mini-Sequences:

| | | |
|--------|---|---|
| 17-314 | Formal Methods *Combined with 17-324 | 6 |
| 17-324 | Advanced Formal Methods * | 6 |
| 17-612 | Business and Marketing Strategy **Combined with either 17-626 or 17-627 | 6 |
| 17-626 | Requirements for Information Systems ** | 6 |
| 17-627 | Requirements for Embedded Systems ** | 6 |
| 17-322 | Agile Methods ***Combined with 17-332 and 17-442 | 6 |
| 17-332 | Software Project Management *** | 6 |
| 17-442 | Software Management Theory *** | 6 |
| 17-323 | Quality Assurance ****Combined with 17-443 | 6 |
| 17-443 | Quality Management **** | 6 |
| 17-335 | Software Architectures May be combined additionally with any of the above to achieve 9+ units total. | 6 |

Crosslisted courses allowed.

Additional courses may count with prior approval by the concentration director.

Computer Science in Society & Industry Elective: a course addressing problems related to existing and emerging technologies and their associated social, political, legal, business, and organizational contexts (minimum 9 units required):

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-334 | Usable Privacy and Security | 9 |

| | | |
|--------|----------------------------------|----|
| 17-562 | Law of Computer Technology | 9 |
| 19-403 | Policies of Wireless Systems | 12 |
| 70-311 | Organizational Behavior | 9 |
| 70-415 | Introduction to Entrepreneurship | 9 |
| 70-471 | Supply Chain Management | 9 |

Crosslisted courses allowed.

See concentration website for additional course options; additional courses may be counted if prior-approval is given by the Concentration Director.

Students can apply one semester of a senior honors research thesis or research-based independent study in a topic related to this concentration, as approved by the concentration director/advisor, as one of the elective courses for this concentration. This research must have a significant communication component, including a paper or technical report, and a poster presentation. Any research course can count for at most 12 units toward the concentration and can count for at most one elective. Consult with the concentration director on what elective can be replaced in this option.

Internship and Reflection

The concentration requires a software engineering internship of a minimum of 8 full-time weeks in an industrial setting (i.e., integrated into a team and exposed to industry pressures). The student may work in development, management, quality assurance, or other relevant positions. Students should confirm with the director that an internship is appropriate, but internships that fulfill the criteria will be accepted after the fact. Students must further complete:

| | | |
|--------|---------------------------------|---|
| 17-415 | Software Engineering Reflection | 6 |
|--------|---------------------------------|---|

Double Counting

No more than two of the courses used to fulfill the concentration requirements may be counted towards any other degree or concentration. SCS General Education requirements do not count towards this restriction.

Advising and Management

The concentration coordinator is responsible for academic advising, handling exceptions and updating the curriculum each year, in consultation with faculty in the Institute for Software Research.

Students who are interested in pursuing this concentration should contact the concentration coordinator for an initial advising consultation.

School of Computer Science Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

Software Societal Systems Courses

08-200 Ethics and Policy Issues in Computing

Spring: 9 units

In this course, students will study the social impacts of computing technology and systems. The course will provide a brief introduction to ethics and to the new and difficult ethical questions modern computing technology presents us with. It will focus on a number of areas in which computers and information technology are having an impact on society including data privacy, social media, and autonomous technologies.

08-722 Data Structures for Application Programmers

Fall and Spring: 6 units

This course is an introduction to Data Structures and a few fundamental algorithms for students with some prior programming experience (functions, loops and arrays mainly in Java). It covers the conceptual and implementation views of some common data structures and algorithms. It also goes over the Java Collections (such as List, ArrayList, LinkedList, Set, HashSet, TreeSet, Map, HashMap, TreeMap, PriorityQueue) to solidify the understanding of the data structures. There is an introduction to the analysis of algorithms that operate on them. Following learning-by-doing methodology, there will be many repetitions of writing code and reviews of the items covered in lectures. Students are required to be familiar with Java Programming before taking this course. Those who are not are encouraged to take 08-671 in mini 1 before taking this course. Students are required to have a reasonably modern laptop computer on which install the Java software used for this course.

SCS Interdisciplinary Courses

07-070 Teaching Techniques for Computer Science

Fall and Spring: 2 units

This course is a broad introduction to teaching techniques and DEI issues in the context of computer science education. It is targeted to first-time undergraduate and graduate SCS TAs, with the goal of providing instruction, hands-on practice, and feedback to TAs to improve their instructional proficiency.

07-090 Artificial Intelligence Practicum

All Semesters: 3 units

This course is for Artificial Intelligence students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their AI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their AI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

07-120 Introduction to Software Construction

Fall and Spring: 6 units

Writing software can be very challenging. While software is often written to solve difficult problems, or implement complex algorithms, there are also challenges in the writing of software itself. In this course, students will learn the software construction skills that will help them throughout their career, both as students, and beyond. Students should expect to learn how to decompose an assignment/problem into subtasks, how to track their progress using milestones, evaluating sub regions of code for correctness, as well as finding and fixing faults in code. Students should expect to participate in a variety of in class activities, as well as work on a project implementing the skills they are learning in class.

Prerequisite: 15-112

07-128 First Year Immigration Course

Fall: 3 units

The First Year Immigration Course is taken by first-semester School of Computer Science students on the Pittsburgh campus. The course is designed to acquaint incoming students with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS First Year students ONLY.

07-129 Freshmen Immigration Course

Fall: 3 units

The Freshman Immigration Course is taken by first-semester Computer Science majors on the Doha campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

07-131 Great Practical Ideas for Computer Scientists

Fall: 2 units

SECTION A IS OPEN TO SCS FIRST YEAR STUDENTS ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. Only undergraduate students will be able to enroll in this course.

07-135 Grand Challenge First-Year Seminar: Designing Better Human-AI Futures

Spring: 9 units

This course will explore the societal impacts of artificial intelligence (AI) based decision-making systems, especially focusing on the societal biases they may enhance or reduce. Students will gain a fundamental understanding of how these systems are designed and work, as well as the role of data in mitigating or enhancing biases. The course is multidisciplinary in nature and brings together social scientists, engineers, data scientists, and designers to tackle the grand challenge of dealing with issues of bias and fairness in Human-AI collaborative systems, ranging from the data that is used to train them, to their human creators that are responsible for deciding how they work and get used. Students will investigate policy, technology and societal elements aimed at reducing and mitigating the impact of AI biases that can negatively impact society, especially its vulnerable members.

07-180 Concepts in Artificial Intelligence

Spring: 5 units

The course will introduce students to the main foundational concepts and techniques used in Artificial Intelligence (AI), including representation, heuristic search, probabilistic reasoning, decision making, and machine learning. Concepts will be grounded in a range of real-world applications in which AI is currently used. Students will be introduced to ethical issues surrounding AI, as well as the potential future of a world in which AI is commonplace. Programming and written assignments will enable students to get a feel for how to implement and use AI techniques.

Prerequisites: 15-112 or 15-122

Course Website: <https://canvas.cmu.edu/courses/8266> (<https://canvas.cmu.edu/courses/8266/>)

07-300 Research and Innovation in Computer Science

Fall: 9 units

This Fall course is the first part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Course topics will include the following: an overview of important things to know about how research and innovation works in the field of computer science; a survey of the current cutting-edge of computer science research, both here at Carnegie Mellon and elsewhere; critical thinking skills when reading research publications that disagree with each other; strategies for coping with open-ended problems; and technical communication skills for computer scientists. Students will also match up with a faculty mentor for a potential Technology Innovation Project (to be performed in the Spring), put together a detailed plan of attack for that project, and start to get up to speed (including background reading, etc.). This course can be used to satisfy the Technical Communications requirement for the CS major.

Prerequisites: 76-101 Min. grade C or 76-102 Min. grade C or (76-106 Min. grade C and 76-107 Min. grade C) or (76-106 Min. grade C and 76-108 Min. grade C) or (76-108 Min. grade C and 76-107 Min. grade C)

07-400 Research Practicum in Computer Science

Spring: 12 units

This Spring course is the second part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Building directly upon 15-300 (the prerequisite for this course), students will conduct a semester-long independent research project, under the guidance of both the course staff and a faculty project mentor. The course does not meet for lecture or recitations. Instead, the students will spend their time working on their research projects, and will also meet with course staff on a bi-weekly basis to discuss their progress. Students will prepare a written report and a poster presentation at the end of the semester to describe what they have accomplished.

Prerequisites: 15-300 or 07-300

07-590 Independent Study in CS Education (Undergraduate)

Fall and Spring

Description: An independent study course to allow motivated students to work on CS education projects under the supervision of a faculty advisor. Includes the development of a pedagogical study, reading of research papers or texts on CS education, or other suitable activities to learn about the teaching of computer science. Presentation of research or study results required. Independent studies are usually one semester in duration and require prior approval from the faculty advisor and the School of Computer Science.

07-599 SCS Honors Undergraduate Research Thesis

Fall and Spring

Available only to students registered in the CS Senior Research Thesis Program.

07-690 Independent Study in CS Education (Masters)

Fall and Spring

Description: An independent study course to allow motivated students to work on CS education projects under the supervision of a faculty advisor. Includes the development of a pedagogical study, reading of research papers or texts on CS education, or other suitable activities to learn about the teaching of computer science. Presentation of research or study results required. Independent studies are usually one semester in duration and require prior approval from the faculty advisor and the School of Computer Science.

Computational Biology Courses

02-201 Programming for Scientists

Fall and Spring: 10 units

Provides a practical introduction to programming for students with little or no prior programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments will be given in other programming languages such as Python and Java to highlight the commonalities and differences between languages. No prior programming experience is assumed, and no biology background is needed. Analytical skills and mathematical maturity are required. Course not open to CS majors.

02-218 Introduction to Computational Medicine

All Semesters: 3 units

This course is an introduction to computational methods relevant to the diagnosis and treatment of human diseases. It is the microcourse version of 02-518, Computational Medicine. The course begins with an introduction to the field of Medicine, and an overview of the primary clinical tasks associated with Computational Medicine (phenotyping; biomarker discovery; predictive modeling). Next, we provide an introduction to several Machine Learning techniques, and how those techniques can be used to perform the clinical tasks. For the remainder of the course, students will be guided through the analysis of a clinical data set to gain experience with these techniques. No prior experience with Medicine, Machine Learning, or computer programming is required. Students will be graded based on quizzes and one homework.

02-223 Personalized Medicine: Understanding Your Own Genome

Fall: 9 units

Do you want to know how to discover the tendencies hidden in your genome? Since the first draft of a human genome sequence became available at the start of this century, the cost of genome sequencing has decreased dramatically. Personal genome sequencing will likely become a routine part of medical exams for patients for prognostic and diagnostic purposes. Personal genome information will also play an increasing role in lifestyle choices, as people take into account their own genetic tendencies. Commercial services such as 23andMe have already taken first steps in this direction. Computational methods for mining large-scale genome data are being developed to unravel the genetic basis of diseases and assist doctors in clinics. This course introduces students to biological, computational, and ethical issues concerning use of personal genome information in health maintenance, medical practice, biomedical research, and policymaking. We focus on practical issues, using individual genome sequences (such as that of Nobel prize winner James Watson) and other population-level genome data. Without requiring any background in biology or CS, we begin with an overview of topics from genetics, molecular biology, stats, and machine learning relevant to the modern personal genome era. We then cover scientific issues such as how to discover your genetic ancestry and how to learn from genomes about migration and evolution of human populations. We discuss medical aspects such as how to predict whether you will develop diseases such as diabetes based on your own genome, how to discover disease-causing genetic mutations, and how genetic information can be used to recommend clinical treatments.

02-250 Introduction to Computational Biology

Spring: 12 units

This class provides a general introduction to computational tools for biology. The course is divided into two halves. The first half covers computational molecular biology and genomics. It examines important sources of biological data, how they are archived and made available to researchers, and what computational tools are available to use them effectively in research. In the process, it covers basic concepts in statistics, mathematics, and computer science needed to effectively use these resources and understand their results. Specific topics covered include sequence data, searching and alignment, structural data, genome sequencing, genome analysis, genetic variation, gene and protein expression, and biological networks and pathways. The second half covers computational cell biology, including biological modeling and image analysis. It includes homework requiring modification of scripts to perform computational analyses. The modeling component includes computer models of population dynamics, biochemical kinetics, cell pathways, and neuron behavior. The imaging component includes the basics of machine vision, morphological image analysis, image classification and image-derived models. The course is taught under two different numbers. The lectures are the same for both but recitations and examinations are separate. 02-250 is intended primarily for computational biology, computer science, statistics or engineering majors at the undergraduate or graduate level who have had prior experience with computer science or programming. 03-250 is intended primarily for biological sciences or biomedical engineering majors who have had limited prior experience with computer science or programming. Students may not take both 02-250 and 03-250 for credit. Prerequisite: (02-201 or 15-110 or 15-112), or permission of the instructors. Prerequisites: (02-201 or 15-110 or 15-112) and (03-151 or 03-131 or 03-121)

Course Website: <http://www.cbd.cmu.edu/education/undergraduate-courses/introduction-to-computational-biology/>

02-251 Great Ideas in Computational Biology

Spring: 12 units

This 12-unit course provides an introduction to many of the great ideas that have formed the foundation for the recent transformation of life sciences into a fully-fledged computational discipline. Extracting biological understanding from both large and small data sets now requires the use and design of novel algorithms, developed in the field of computational biology. This gateway course is intended as a first exposure to computational biology for first-year undergraduates in the School of Computer Science, although it is open to other computationally minded students who are interested in exploring the field. Students will learn fundamental algorithmic and machine learning techniques that are used in modern biological investigations, including algorithms to process string, graph, and image data. They will use these techniques to answer questions such as "How do we reconstruct the sequence of a genome?", "How do we infer evolutionary relationships among many species?", and "How can we predict each gene's biological role?" on biological data. Previous exposure to molecular biology is not required, as the instructors will provide introductory materials as needed. After completion of the course, students will be well equipped to tackle advanced computational challenges in biology.

Prerequisites: (15-112 or 02-201) and (15-151 or 21-127 or 21-128)

02-261 Quantitative Cell and Molecular Biology Laboratory

Fall and Spring

This is an introductory laboratory-based course designed to teach basic biological laboratory skills used in exploring the quantitative nature of biological systems and the reasoning required for performing research in computational biology. Over the course of the semester, students will design and perform multiple modern experiments and quantitatively analyze the results of these experiments. During this course students will also have an opportunity to use techniques learned during the course to experimentally answer an open question. Designing the experiments will require students to think critically about the biological context of the experiments as well as the necessary controls to ensure interpretable experimental results. During this course students will gain experience in many aspects of scientific research, including: sequencing DNA, designing and performing PCR for a variety of analyses, maintaining cell cultures, taking brightfield and fluorescent microscopy images, developing methods for automated analysis of cell images, communicating results to peers and colleagues. Course Outline: (1) 3-hour lab per week, (1) 1-hour lecture per week.

Prerequisites: 15-112 or 02-201

02-262 Computation and Biology Integrated Research Lab

All Semesters

Modern biological research is heavily interdisciplinary in nature requiring the use of a diverse set of experimental techniques and computational analysis. This course provides students with a modern research experience while training them to communicate and collaborate in an interdisciplinary setting to better prepare them to join the workforce as members of interdisciplinary teams. This will be accomplished by focusing efforts on a real research problem requiring sophisticated experimentation and computation for success. Class time will include both laboratory research time (wet lab and computational) and activities designed to teach and practice communication methods for interdisciplinary teams. Students are expected to have a strong background in biology or computation and an interest in both. Pre-requisites include either (03-117 or 03-124 or 03-343) or (15-112 or equivalent)

02-317 Algorithms in Nature

Intermittent: 9 units

Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. No prior biological knowledge required.

Prerequisites: 15-210 and 15-251

Course Website: <http://www.algorithmsinnature.org>**02-319 Genomics and Epigenetics of the Brain**

Fall: 9 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.

Prerequisites: (03-121 or 03-151) and (03-220 or 03-221) and (15-121 or 15-112 or 15-110 or 02-201)

02-331 Modeling Evolution

Spring: 12 units

Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.

Prerequisites: 15-112 and 21-241 and (36-218 or 21-325 or 36-225 or 15-259)

02-402 Computational Biology Seminar

Fall and Spring: 3 units

This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80% of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

02-403 Special Topics in Bioinformatics and Computational Biology

Intermittent: 6 units

A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use ²H, ¹³C or ¹⁵N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

Prerequisites: (02-250 Min. grade C or 03-250 Min. grade C) and 03-121 Min. grade C

02-414 String Algorithms

Intermittent: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.

Prerequisites: 21-128 or 15-151 or 15-127

02-421 Algorithms for Computational Structural Biology

Intermittent: 12 units

Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-425 Computational Methods for Proteogenomics and Metabolomics

Spring: 9 units

Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.

Prerequisites: 02-250 or 02-604 or 02-251

02-450 Automation of Scientific Research

Spring: 9 units

Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.

Prerequisites: (10-701 or 10-315) and 15-122

02-499 Independent Study in Computational Biology

Fall and Spring

The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-500 Undergraduate Research in Computational Biology

Fall and Spring

This course is for undergraduate students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator who will enroll you in the course. 02-250 is a suggested pre-requisite.

Course Website: <https://forms.gle/S1AJX65btkTxwNCw9> (<https://forms.gle/S1AJX65btkTxwNCw9>)

02-510 Computational Genomics

Spring: 12 units

Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

Prerequisites: 15-122 Min. grade C and (15-259 or 36-225 or 36-218 or 36-325)

02-512 Computational Methods for Biological Modeling and Simulation

Fall: 9 units

This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.

Prerequisites: 15-112 or 02-201 or 15-110

02-514 String Algorithms

Fall: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Burrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.

Prerequisite: 15-251

02-515 Advanced Topics in Computational Genomics

Spring: 12 units

Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for critiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-518 Computational Medicine

Fall: 12 units

Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Course Website: <https://sites.google.com/view/computationalmedicine/>**02-530 Cell and Systems Modeling**

Fall: 12 units

This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. Prerequisites: (03-121 or 33-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

02-540 Bioimage Informatics

Intermittent: 12 units

With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

Prerequisites: 02-620 or 10-301 or 10-315 or 10-601 or 10-701

02-601 Programming for Scientists

Fall and Spring: 12 units

Provides a practical introduction to programming for students with little previous programming experience who are interested in science. Fundamental scientific algorithms will be introduced, and extensive programming assignments will be based on analytical tasks that might be faced by scientists, such as parsing, simulation, and optimization. Principles of good software engineering will also be stressed. The course will introduce students to the Go programming language, an industry-supported, modern programming language, the syntax of which will be covered in depth. Other assignments may be given in other programming languages to highlight the commonalities and differences between languages. No biology background is needed. Analytical skills, an understanding of programming basics, and mathematical maturity are required.

Course Website: <http://compeau.cbd.cmu.edu/programming-for-scientists/>**02-602 Professional Issues for Computational and Automated Scientists**

Fall and Spring: 3 units

This course gives Master's in Computational Biology and Master's in Automated Science students the opportunity to develop the professional skills necessary for a successful career in either academia or industry. This course, required in the first semester of both programs, will include assistance with elevator pitches, interview preparation, resume and cover letter writing, networking, and presentation skills. The course will also include opportunities to connect with computational biology professionals as part of industry outreach. The course will meet once a week and is pass/fail only.

02-604 Fundamentals of Bioinformatics

Spring: 12 units

How do we find potentially harmful mutations in your genome? How can we reconstruct the Tree of Life? How do we compare similar genes from different species? These are just three of the many central questions of modern biology that can only be answered using computational approaches. This 12-unit course will delve into some of the fundamental computational ideas used in biology and let students apply existing resources that are used in practice every day by thousands of biologists. The course offers an opportunity for students who possess an introductory programming background to become more experienced coders within a biological setting. As such, it presents a natural next course for students who have completed 02-601.

02-605 Professional Issues in Automated Science

Spring: 3 units

This course gives MS in Automated Science students an opportunity to develop professional skills necessary for a successful career in computational biology. This course will include assistance with resume writing, interview preparation, presentation skills, and job search techniques. This course will also include opportunities to network with computational biology professionals and academic researchers.

02-613 Algorithms and Advanced Data Structures

Fall and Spring: 12 units

The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. 02-250 is a suggested prerequisite for undergraduates.

02-614 String Algorithms

Intermittent: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous amounts of collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in genomics will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases.

Prerequisites: 15-151 or 15-127 or 21-128

02-620 Machine Learning for Scientists

Spring: 12 units

With advances in scientific instruments and high-throughput technology, scientific discoveries are increasingly made from analyzing large-scale data generated from experiments or collected from observational studies. Machine learning methods that have been widely used to extract complex patterns from large speech, text, and image data are now being routinely applied to answer scientific questions in biology, bioengineering, and medicine. This course is intended for graduate students interested in learning machine learning methods for scientific data analysis and modeling. It will cover classification and regression techniques such as logistic regression, random forest regression, Gaussian process regression, decision trees, and support vector machines; unsupervised learning methods such as clustering algorithms, mixture models, and hidden Markov models; probabilistic graphical models and deep learning methods; and learning theories such as PAC learning and VC dimension. The course will focus on applications of these methods in genomics and medicine. Programming skills and basic knowledge of linear algebra, probability, statistics are assumed.

Prerequisite: 02-680

02-651 New Technologies and Future Markets

Fall: 12 units

This course focuses on technological trends and how these trends can help shape or disrupt new and existing markets. Students will learn to identify, analyze, and synthesize emerging trends and perform detailed research on how these trends can influence and create markets. By understanding the drivers behind these trends students will be able to identify key market opportunity inflection points in biotechnology as well as the relationship between business processes and information technology (IT). Students will also learn to assess some information technologies and the potential of applying them to solve problems and create commercially viable solutions. The course is designed for the student interested in finding new venture opportunities on the cutting edge of technology and finding and evaluating the opportunities for further development. For MS Biotechnology Innovation and Computation students only.

Prerequisite: 11-695

02-654 Biotechnology Enterprise Development

Fall: 12 units

In this course students learn how to develop a biotech start-up, create a Minimum Viable Product (MVP), business model and strategy for the product. Students will learn about business modeling, customer development, customer validation, proposal, product branding, and marketing for their product. The course will require students to spend most time to validate their start up concept and prototypes with potential customers and adapt to critical feedback and revise their respective value propositions accordingly. Students learn to balance technical product development with customer requirements, business strategy and budget constraints. This course provides real world, hands-on learning on what it is like to start a company. Different business modeling will be covered. By understanding customer discovery and validation concepts will aid students to effectively modify their original concepts to meet market demands. Student teams will learn how to revise, improve their prototype by the end of the term. This is a fast paced course in which students are expected to spend most of the time outside of the classroom to interact with potential customers to validate, test, verify, and integrate essential elements for their start-up business proposal. Up to now, students have been learning some technologies and methods for solving problems in the life science industry and build a prototype for their start-up. However, a new venture proposal is not a collection of isolated bits. It should be thorough validated via customer's inputs and market needs to tell a single story of how the venture will reach its end goals. Final deliverable is creation and presentation of a well explicated, business proposal in addition to a product prototype corresponding to the business proposal.

Prerequisites: 11-695 and 02-651

02-680 Essential Mathematics and Statistics for Scientists

Fall: 9 units

This course rigorously introduces fundamental topics in mathematics and statistics to first-year master's students as preparation for more advanced computational coursework. Topics are sampled from information theory, graph theory, proof techniques, phylogenetics, combinatorics, set theory, linear algebra, neural networks, probability distributions and densities, multivariate probability distributions, maximum likelihood estimation, statistical inference, hypothesis testing, Bayesian inference, and stochastic processes. Students completing this course will obtain a broad skillset of mathematical techniques and statistical inference as well as a deep understanding of mathematical proof. They will have the quantitative foundation to immediately step into an introductory master's level machine learning or automation course. This background will also serve students well in advanced courses that apply concepts in machine learning to scientific datasets, such as 02-710 (Computational Genomics) or 02-750 (Automation of Biological Research). The course grade will be computed as the result of homework assignments, midterm tests, and class participation.

02-699 Independent Study in Computational Biology

Fall and Spring

The student will, under the individual guidance of a faculty member, read and digest process papers or a textbook in an advanced area of computational biology not offered by an existing course at Carnegie Mellon. The student will demonstrate their mastery of the material by a combination of one or more of the following: oral discussions with the faculty member; exercises set by the faculty member accompanying the readings; and a written summary synthesizing the material that the student learned. Permission required.

02-700 M.S. Thesis Research

Fall and Spring

This course is for M.S. students who wish to do supervised research for academic credit with a Computational Biology faculty member. Interested students should first contact the Professor with whom they would like to work. If there is mutual interest, the Professor will direct you to the Academic Programs Coordinator, who will enroll you in the course.

Course Website: <https://forms.gle/tDKDs1EujvXAApYK7> (<https://forms.gle/tDKDs1EujvXAApYK7/>)**02-702 Computational Biology Seminar**

Fall and Spring: 3 units

This course consists of weekly invited presentations on current computational biology research topics by leading scientists. Attendance is mandatory for a passing grade. You must sign in and attend at least 80 percent of the seminars. See course website for seminar locations. Some will be at the University of Pittsburgh and some will be at Carnegie Mellon.

Course Website: <https://www.compbio.cmu.edu/seminar-series/index.html> (<https://www.compbio.cmu.edu/seminar-series/>)**02-703 Special Topics in Bioinformatics and Computational Biology**

Intermittent: 6 units

A decade ago, mass spectrometry (MS) was merely a qualitative research technique allowing the analysis of samples regarding the presence of specific biomolecules. However, as MS has turned quantitative, more sophisticated experiments can be performed, such as the recording of signal transduction kinetics and the analysis of the composition of protein complexes and organelles. This makes MS-based proteomics a powerful method to study spatiotemporal protein dynamics. The development of relative quantification approaches, which generally use ^2H , ^{13}C or ^{15}N isotope labels, has especially led to an increase in quantification accuracy and set off numerous new experimental approaches to study protein regulation. In this mini-course, we will cover mass spectrometry principles, discuss classical as well as current primary literature addressing method development and quantitative analysis, and highlight state-of-the-art biological studies that employ MS. A combination of lectures, student presentations, and written exercises will establish a thorough knowledge of current bio-analytical MS approaches.

02-710 Computational Genomics

Spring: 12 units

Dramatic advances in experimental technology and computational analysis are fundamentally transforming the basic nature and goal of biological research. The emergence of new frontiers in biology, such as evolutionary genomics and systems biology is demanding new methodologies that can confront quantitative issues of substantial computational and mathematical sophistication. From the computational side this course focuses on modern machine learning methodologies for computational problems in molecular biology and genetics, including probabilistic modeling, inference and learning algorithms, data integration, time series analysis, active learning, etc. This course counts as a CSD Applications elective

02-711 Computational Molecular Biology and Genomics

Spring: 12 units

An advanced introduction to computational molecular biology, using an applied algorithms approach. The first part of the course will cover established algorithmic methods, including pairwise sequence alignment and dynamic programming, multiple sequence alignment, fast database search heuristics, hidden Markov models for molecular motifs and phylogeny reconstruction. The second part of the course will explore emerging computational problems driven by the newest genomic research. Course work includes four to six problem sets, one midterm and final exam. Prerequisites: (03-151 or 03-121) and 15-122

02-712 Computational Methods for Biological Modeling and Simulation

Fall: 12 units

This course covers a variety of computational methods important for modeling and simulation of biological systems. It is intended for graduates and advanced undergraduates with either biological or computational backgrounds who are interested in developing computer models and simulations of biological systems. The course will emphasize practical algorithms and algorithm design methods drawn from various disciplines of computer science and applied mathematics that are useful in biological applications. The general topics covered will be models for optimization problems, simulation and sampling, and parameter tuning. Course work will include problem sets with significant programming components and independent or group final projects.

Prerequisites: (15-110 or 15-112) and (02-201 or 02-613)

02-714 String Algorithms

Fall: 12 units

Provides an in-depth look at modern algorithms used to process string data, particularly those relevant to genomics. The course will cover the design and analysis of efficient algorithms for processing enormous collections of strings. Topics will include string search; inexact matching; string compression; string data structures such as suffix trees, suffix arrays, and searchable compressed indices; and the Borrows-Wheeler transform. Applications of these techniques in biology will be presented, including genome assembly, transcript assembly, whole-genome alignment, gene expression quantification, read mapping, and search of large sequence databases. No knowledge of biology is assumed, and the topics covered will be of use in other fields involving large collections of strings. Programming proficiency is required.

Prerequisite: 15-251

02-715 Advanced Topics in Computational Genomics

Spring: 12 units

Research in biology and medicine is undergoing a revolution due to the availability of high-throughput technology for probing various aspects of a cell at a genome-wide scale. The next-generation sequencing technology is allowing researchers to inexpensively generate a large volume of genome sequence data. In combination with various other high-throughput techniques for epigenome, transcriptome, and proteome, we have unprecedented opportunities to answer fundamental questions in cell biology and understand the disease processes with the goal of finding treatments in medicine. The challenge in this new genomic era is to develop computational methods for integrating different data types and extracting complex patterns accurately and efficiently from a large volume of data. This course will discuss computational issues arising from high-throughput techniques recently introduced in biology, and cover very recent developments in computational genomics and population genetics, including genome structural variant discovery, association mapping, epigenome analysis, cancer genomics, and transcriptome analysis. The course material will be drawn from very recent literature. Grading will be based on weekly write-ups for critiques of the papers to be discussed in the class, class participation, and a final project. It assumes a basic knowledge of machine learning and computational genomics.

02-717 Algorithms in Nature

Fall: 12 units

Computer systems and biological processes often rely on networks of interacting entities to reach joint decisions, coordinate and respond to inputs. There are many similarities in the goals and strategies of biological and computational systems which suggest that each can learn from the other. These include the distributed nature of the networks (in biology molecules, cells, or organisms often operate without central control), the ability to successfully handle failures and attacks on a subset of the nodes, modularity and the ability to reuse certain components or sub-networks in multiple applications and the use of stochasticity in biology and randomized algorithms in computer science. In this course we will start by discussing classic biologically motivated algorithms including neural networks (inspired by the brain), genetic algorithms (sequence evolution), non-negative matrix factorization (signal processing in the brain), and search optimization (ant colony formation). We will then continue to discuss more recent bi-directional studies that have relied on biological processes to solve routing and synchronization problems, discover Maximal Independent Sets (MIS), and design robust and fault tolerant networks. In the second part of the class students will read and present new research in this area. Students will also work in groups on a final project in which they develop and test a new biologically inspired algorithm. See also: www.algorithmsinnature.org no prior biological knowledge required.

02-718 Computational Medicine

Fall: 12 units

Modern medical research increasingly relies on the analysis of large patient datasets to enhance our understanding of human diseases. This course will focus on the computational problems that arise from studies of human diseases and the translation of research to the bedside to improve human health. The topics to be covered include computational strategies for advancing personalized medicine, pharmacogenomics for predicting individual drug responses, metagenomics for learning the role of the microbiome in human health, mining electronic medical records to identify disease phenotypes, and case studies in complex human diseases such as cancer and asthma. We will discuss how machine learning methodologies such as regression, classification, clustering, semi-supervised learning, probabilistic modeling, and time-series modeling are being used to analyze a variety of datasets collected by clinicians. Class sessions will consist of lectures, discussions of papers from the literature, and guest presentations by clinicians and other domain experts. Grading will be based on homework assignments and a project. 02-250 is a suggested pre-requisite.

Prerequisites: 10-315 or (10-701 and 10-601 and 10-401)

Course Website: <https://sites.google.com/view/computationalmedicine/>**02-719 Genomics and Epigenetics of the Brain**

Fall: 12 units

This course will provide an introduction to genomics, epigenetics, and their application to problems in neuroscience. The rapid advances in single cell sequencing and other genomic technologies are revolutionizing how neuroscience research is conducted, providing tools to study how different cell types in the brain produce behavior and contribute to neurological disorders. Analyzing these powerful new datasets requires a foundation in molecular neuroscience as well as key computational biology techniques. In this course, we will cover the biology of epigenetics, how proteins sitting on DNA orchestrate the regulation of genes. In parallel, programming assignments and a project focusing on the analysis of a primary genomic dataset will teach principles of computational biology and their applications to neuroscience. The course material will also serve to demonstrate important concepts in neuroscience, including the diversity of neural cell types, neural plasticity, the role that epigenetics plays in behavior, and how the brain is influenced by neurological and psychiatric disorders. Although the course focuses on neuroscience, the material is accessible and applicable to a wide range of topics in biology.

Prerequisites: (03-151 or 03-121) and 03-220 and (02-201 or 15-110 or 15-121)

02-721 Algorithms for Computational Structural Biology

Intermittent: 12 units

Some of the most interesting and difficult challenges in computational biology and bioinformatics arise from the determination, manipulation, or exploitation of molecular structures. This course will survey these challenges and present a variety of computational methods for addressing them. Topics will include: molecular dynamics simulations, computer-aided drug design, and computer-aided protein design. The course is appropriate for both students with backgrounds in computer science and those in the life sciences.

02-725 Computational Methods for Proteogenomics and Metabolomics

Spring: 12 units

Proteomics and metabolomics are the large scale study of proteins and metabolites, respectively. In contrast to genomes, proteomes and metabolomes vary with time and the specific stress or conditions an organism is under. Applications of proteomics and metabolomics include determination of protein and metabolite functions (including in immunology and neurobiology) and discovery of biomarkers for disease. These applications require advanced computational methods to analyze experimental measurements, create models from them, and integrate with information from diverse sources. This course specifically covers computational mass spectrometry, structural proteomics, proteogenomics, metabolomics, genome mining and metagenomics.

Prerequisites: 02-250 or 02-251 or 02-604

02-730 Cell and Systems Modeling

Fall: 12 units

This course will introduce students to the theory and practice of modeling biological systems from the molecular to the organism level with an emphasis on intracellular processes. Topics covered include kinetic and equilibrium descriptions of biological processes, systematic approaches to model building and parameter estimation, analysis of biochemical circuits modeled as differential equations, modeling the effects of noise using stochastic methods, modeling spatial effects, and modeling at higher levels of abstraction or scale using logical or agent-based approaches. A range of biological models and applications will be considered including gene regulatory networks, cell signaling, and cell cycle regulation. Weekly lab sessions will provide students hands-on experience with methods and models presented in class. Course requirements include regular class participation, bi-weekly homework assignments, a take-home exam, and a final project. The course is designed for graduate and upper-level undergraduate students with a wide variety of backgrounds. The course is intended to be self-contained but students may need to do some additional work to gain fluency in core concepts. Students should have a basic knowledge of calculus, differential equations, and chemistry as well as some previous exposure to molecular biology and biochemistry. Experience with programming and numerical computation is useful but not mandatory. Laboratory exercises will use MATLAB as the primary modeling and computational tool augmented by additional software as needed. *THIS COURSE WILL BE AT PITT

Prerequisites: (33-121 or 03-121 or 03-151) and (03-232 or 03-231) and 21-112 and 09-105

Course Website: <https://sites.google.com/site/cellandsystemsmodeling/>**02-731 Modeling Evolution**

Spring: 12 units

Some of the most serious public health problems we face today, from drug-resistant bacteria, to cancer, all arise from a fundamental property of living systems and #8212; their ability to evolve. Since Darwin's theory of natural selection was first proposed, we have begun to understand how heritable differences in reproductive success drive the adaptation of living systems. This makes it intuitive and tempting to view evolution from an optimization perspective. However, genetic drift, phenotypic trade-offs, constraints, and changing environments, are among the many factors that may limit the optimizing force of natural selection. This tug-of-war between selection and drift, between the forces that produce variation in a population, and the forces suppressing this variation, make evolutionary processes much more complex to model and understand than previously thought. The aim of this class is to provide an introduction into the theoretical formalism necessary to understand how biological systems are shaped by the forces and constraints driving evolutionary dynamics.

Prerequisites: 15-112 and 21-241 and (21-325 or 36-218 or 15-259 or 36-225)

02-740 Bioimage Informatics

Intermittent: 12 units

With the rapid advance of bioimaging techniques and fast accumulation of bioimage data, computational bioimage analysis and modeling are playing an increasingly important role in understanding of complex biological systems. The goals of this course are to provide students with the ability to understand a broad set of practical and cutting-edge computational techniques to extract knowledge from bioimages.

02-750 Automation of Scientific Research

Spring: 12 units

Automated scientific instruments are used widely in research and engineering. Robots dramatically increase the reproducibility of scientific experiments, and are often cheaper and faster than humans, but are most often used to execute brute-force sweeps over experimental conditions. The result is that many experiments are "wasted" on conditions where the effect could have been predicted. Thus, there is a need for computational techniques capable of selecting the most informative experiments. This course will introduce students to techniques from Artificial Intelligence and Machine Learning for automatically selecting experiments to accelerate the pace of discovery and to reduce the overall cost of research. Real-world applications from Biology, Bioengineering, and Medicine will be studied. Grading will be based on homeworks and two exams. The course is intended to be self-contained, but students should have a basic knowledge of biology, programming, statistics, and machine learning.

Prerequisites: 10-601 or 10-701 or 02-620

02-760 Laboratory Methods for Computational Biologists

Fall and Spring: 9 units

Computational biologists frequently focus on analyzing and modeling large amounts of biological data, often from high-throughput assays or diverse sources. It is therefore critical that students training in computational biology be familiar with the paradigms and methods of experimentation and measurement that lead to the production of these data. This one-semester laboratory course gives students a deeper appreciation of the principles and challenges of biological experimentation. Students learn a range of topics, including experimental design, structural biology, next generation sequencing, genomics, proteomics, bioimaging, and high-content screening. Class sessions are primarily devoted to designing and performing experiments in the lab using the above techniques. Students are required to keep a detailed laboratory notebook of their experiments and summarize their resulting data in written abstracts and oral presentations given in class-hosted lab meetings. With an emphasis on the basics of experimentation and broad views of multiple cutting-edge and high-throughput techniques, this course is appropriate for students who have never taken a traditional undergraduate biology lab course, as well as those who have and are looking for introductory training in more advanced approaches. Grading: Letter grade based on class participation, laboratory notebooks, experimental design assignments, and written and oral presentations. 02-250 is a suggested pre-requisite.

02-761 Laboratory Methods for Automated Biology I

Fall: 12 units

In order to rapidly generate reproducible experimental data, many modern biology labs leverage some form of laboratory automation to execute experiments. In the not so distant future, the use of laboratory automation will continue to increase in the biological lab to the point where many labs will be fully automated. Therefore, it is critical for automation scientists to be familiar with the principles, experimental paradigms, and techniques for automating biological experimentation with an eye toward the fully automated laboratory. In this laboratory course, students will learn about various automatable experimental methods, design of experiments, hardware for preparing samples and executing automated experiments, and software for controlling that hardware. These topics will be taught in lectures as well as through laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on liquid handling, plate control, plate reading, and remote control of the automated system based on experimental data. The second project will be focused on the design, implementation, and analysis of a high content screening campaign using fluorescence microscopy, image analysis, and tissue culture methods.

02-762 Laboratory Methods for Automated Biology II

Spring: 12 units

This laboratory course provides a continuation and extension of experiences in 02-761. Instruction will consist of lectures and laboratory experience using multi-purpose laboratory robotics. During weekly laboratory time, students will complete and integrate parts of two larger projects. The first project will be focused on the execution of a molecular biology experiment requiring nucleic acid extraction, library preparation for sequencing, and quality control. The second project will be focused on the implementation and execution of automated methods using active learning techniques to direct the learning of a predictive model for a large experimental space (such as learning the effects of many possible drugs on many possible targets). Grading will be based on lab and project completion and quality.

Prerequisite: 02-761

02-764 Automated Science Capstone II

Spring: 12 units

This course consists of small group projects on development, implementation and/or execution of automated science campaigns in collaboration with industry and/or academic partners. This course may only be taken as part of a continuous sequence with 02-763. Enrollment is only open to M.S. in Automated Science students.

Computer Science Courses

15-050 Study Abroad

All Semesters

Students who are interested in studying abroad should first contact the Office of International Education. More information on Study Abroad is available on OIE's Study Abroad page and at the CS Undergraduate Office.

15-090 Computer Science Practicum

All Semesters: 3 units

This course is for Computer Science students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their CS curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their CS education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

Course Website: <https://csd.cs.cmu.edu/course-profiles/15-090-Computer-Science-Practicum> (<https://csd.cs.cmu.edu/course-profiles/15-090-Computer-Science-Practicum/>)

15-104 Introduction to Computing for Creative Practice

Fall: 10 units

An introduction to fundamental computing principles and programming techniques for creative cultural practices, with special consideration to applications in music, design and the visual arts. Intended for students with little to no prior programming experience, the course develops skills and understanding of text-based programming in a procedural style, including idioms of sequencing, selection, iteration, and recursion. Topics include data organization (arrays, files, trees), interfaces and abstraction (modular software design, using sensor data and software libraries), basic algorithms (searching and sorting), and computational principles (randomness, concurrency, complexity). Intended for students participating in IDEATe courses or minors who have not taken 15-112.

Course Website: <https://csd.cs.cmu.edu/course-profiles/15-104-Introduction-to-Computing-for-Creative-Practice> (<https://csd.cs.cmu.edu/course-profiles/15-104-Introduction-to-Computing-for-Creative-Practice/>)

15-106 Introduction to Computing for Data Analysis

Spring: 5 units

[Course Pilot] An introductory course in programming for students in statistics-related disciplines using R. Fundamental data types and data structures: booleans, numbers, characters, vectors, matrices, data frames, and lists. Programming constructs: assignment, conditionals, loops, function calls. Processing data: vectorization, "apply" functions, text processing, plotting tools. Additional topics, time permitting: writing functions, using data files, random number generation and simulation. This course is not for credit for SCS majors.

Course Website: <http://www.cs.cmu.edu/~mrmiller/15-106/>

15-110 Principles of Computing

All Semesters: 10 units

A course in fundamental computing principles for students with minimal or no computing background. Programming constructs: sequencing, selection, iteration, and recursion. Data organization: arrays and lists. Use of abstraction in computing: data representation, computer organization, computer networks, functional decomposition, and application programming interfaces. Use of computational principles in problem-solving: divide and conquer, randomness, and concurrency. Classification of computational problems based on complexity, non-computable functions, and using heuristics to find reasonable solutions to complex problems. Social, ethical and legal issues associated with the development of new computational artifacts will also be discussed.

Course Website: <https://www.cs.cmu.edu/~15110/>

15-112 Fundamentals of Programming and Computer Science

All Semesters: 12 units

A technical introduction to the fundamentals of programming with an emphasis on producing clear, robust, and reasonably efficient code using top-down design, informal analysis, and effective testing and debugging. Starting from first principles, we will cover a large subset of the Python programming language, including its standard libraries and programming paradigms. We will also target numerous deployment scenarios, including standalone programs, shell scripts, and web-based applications. This course assumes no prior programming experience. Even so, it is a fast-paced and rigorous preparation for 15-122. Students seeking a more gentle introduction to computer science should consider first taking 15-110. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Course Website: <https://www.cs.cmu.edu/~112/>

15-121 Introduction to Data Structures

Fall: 10 units

A continuation of the process of program design and analysis for students with some prior programming experience (functions, loops, and arrays, not necessarily in Java). The course reinforces object-oriented programming techniques in Java and covers data aggregates, data structures (e.g., linked lists, stacks, queues, trees, and graphs), and an introduction to the analysis of algorithms that operate on those data structures.

Prerequisite: 15-112

Course Website: <http://www.cs.cmu.edu/~mjs/121/index.html> (<http://www.cs.cmu.edu/~mjs/121/>)

15-122 Principles of Imperative Computation

All Semesters: 12 units

For students with a basic understanding of programming (variables, expressions, loops, arrays, functions). Teaches imperative programming and methods for ensuring the correctness of programs. Students will learn the process and concepts needed to go from high-level descriptions of algorithms to correct imperative implementations, with specific application to basic data structures and algorithms. Much of the course will be conducted in a subset of C amenable to verification, with a transition to full C near the end. This course prepares students for 15-213 and 15-210. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Prerequisite: 15-112 Min. grade C

Course Website: <http://www.cs.cmu.edu/~15122/home.shtml> (<http://www.cs.cmu.edu/~15122/home.shtml/>)

15-128 Freshman Immigration Course

Fall: 1 unit

The Freshman Immigration Course is taken by first-semester Computer Science majors on the Pittsburgh campus. The course is designed to acquaint incoming majors with computer science at CMU. Talks range from historical perspectives in the field to descriptions of the cutting edge research being conducted in the School of Computer Science. Enrollment is limited to SCS Freshmen ONLY.

15-129 Freshman Immigration II

Fall: 3 units

This course is ONLY offered at Carnegie Mellon in Qatar. Students and instructors will solve different problems each week by searching the Web and other likely places for answers. The problems will be submitted by other faculty who will grade the quality of the answers. Students will learn strategies and techniques for finding information on the Web more efficiently; learn when to start with a search engine, a subject-oriented directory, or other tools; explore and practice using advanced search syntax for major search engines; experience specialized search engines for images, sound, multimedia, newsgroups, and discussion lists as well as subject-specific search engines; discover valuable resources to help keep you up-to-date in this fast-changing environment.

15-131 Great Practical Ideas for Computer Scientists

Fall: 2 units

THIS COURSE IS OPEN TO CS FRESHMAN ONLY. Throughout your education as a Computer Scientist at Carnegie Mellon, you will take courses on programming, theoretical ideas, logic, systems, etc. As you progress, you will be expected to pick up the so-called "tools of the trade." This course is intended to help you learn what you need to know in a friendly, low-stress, high-support way. We will discuss UNIX, LaTeX, debugging and many other essential tools. Laptop required. (Laptops will be available for those without their own laptops.)

Course Website: <https://www.cs.cmu.edu/~15131/f17/>**15-150 Principles of Functional Programming**

All Semesters: 12 units

An introduction to programming based on a "functional" model of computation. The functional model is a natural generalization of algebra in which programs are formulas that describe the output of a computation in terms of its inputs and #8212;that is, as a function. But instead of being confined to real- or complex-valued functions, the functional model extends the algebraic view to a very rich class of data types, including not only aggregates built up from other types, but also functions themselves as values. This course is an introduction to programming that is focused on the central concepts of function and type. One major theme is the interplay between inductive types, which are built up incrementally; recursive functions, which compute over inductive types by decomposition; and proof by structural induction, which is used to prove the correctness and time complexity of a recursive function. Another major theme is the role of types in structuring large programs into separate modules, and the integration of imperative programming through the introduction of data types whose values may be altered during computation. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Prerequisites: (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and 15-112 Min. grade C

Course Website: <http://www.cs.cmu.edu/~15150/>**15-151 Mathematical Foundations for Computer Science**

Fall: 12 units

CS majors only This course is offered to incoming Computer Science freshmen and focuses on the fundamental concepts in Mathematics that are of particular interest to Computer Science such as logic, sets, induction, functions, and combinatorics. These topics are used as a context in which students learn to formalize arguments using the methods of mathematical proof. This course uses experimentation and collaboration as ways to gain better understanding of the material. Open to CS freshmen only. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Prerequisite: 21-120

Course Website: https://www.math.cmu.edu/~jmackey/151_128/welcome.html**15-155 The Computational Lens**

Spring: 9 units

What is knowable, in principle and in practice? - What does it mean to be intelligent? - Can creativity be automated? - What is the role of randomness in the universe? - How can we achieve provable guarantees of security, privacy, fairness, etc. in various settings? - What does the social network of the world look like? - Do we live in a simulation? Despite their differences, all of these questions are fundamentally about the notion of computation. And all these questions can be put under the following single umbrella: What is computation and how does it shape our understanding of life, science, technology, and society? This course is for anyone interested in these questions and more broadly, anyone interested in the algorithmic lens to tackle hard, foundational problems. Our goal will be to find reliable explanations through modeling and rigorous reasoning. We will discuss great and powerful ideas from the field of theory of computation and see how these ideas shed new light on human reasoning, laws of nature, life, technology, and society.

Prerequisites: 15-110 or 15-104 or 15-112

Course Website: <http://computationallens.com>**15-181 Demystifying AI**

Spring: 9 units

This course will pull back the curtains on artificial intelligence, helping you learn what it is, what it can do, how to use it, how it works, and what can go wrong. This course is designed for students that want to learn about AI and machine learning but don't have the course schedule bandwidth to build up the math and computing background required for full-fledged intro AI and ML courses, such as 15-281 and 10-301. Leveraging high school algebra and basic Python programming skills from 15-110, we'll help you implement key pieces of AI techniques from the nearest neighbor algorithm to simple neural networks. Through in-class activities, weekly recitations, and course assignments, you'll start to learn how to use AI systems, including how to make them "intelligent", what data might be needed, and what can go wrong. Ethical discussions will be woven throughout the course to enable you to think critically about how AI impacts our society.

Prerequisites: 15-112 or 15-110

15-182 Artificial Intelligence for Medicine

Intermittent: 6 units

This course introduces Artificial Intelligence (AI) and its recent applications in medicine for students with no background in computer science. It starts by motivating and defining AI, before folding over to a survey of some of its newest applications to medicine, including diagnosis, prognosis, drug discovery, and recommendations of individualized treatments, to mention just a few. Afterwards, it provides a birds-eye view of some of the major AI techniques, including machine learning, deep neural networks, recommendation systems, ranked retrieval, and probabilistic graphical models. Finally, it concludes with a discussion on some of the concerns related to AI, including ethical issues, job security, society, and healthcare institutions, among others

15-195 Competition Programming I

All Semesters: 5 units

Each year, Carnegie Mellon fields several teams for participation in the ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events. Students who have not yet taken 15-295 should register for 15-195; only students who have already taken 15-295 should register for 15-295 again.

Prerequisite: 15-122 Min. grade C

15-199 Special Topics: Discovering Logic

Intermittent: 3 units

This course is ONLY offered at Carnegie Mellon in Qatar. This course has the purpose of introducing first-year Computer Science students to elements of formal logic as well as to the historical context in which this discipline developed. As all subsequent courses in the CS curriculum rely on students having mastered basic logical notions and skills, it will test and enhance your preparation, thereby putting you in a better position to succeed in the program. It will also help you understand and appreciate how CS came about since Computer Science grew out of logic. The specific knowledge and skills you will learn in is course include: an enhanced ability to research topics, give presentations and write technical prose, some elementary logic, some historical depth into Computer Science, mathematics and logic itself. This course is open to Computer Science freshmen only.

15-210 Parallel and Sequential Data Structures and Algorithms

Fall and Spring: 12 units

Teaches students about how to design, analyze, and program algorithms and data structures. The course emphasizes parallel algorithms and analysis, and how sequential algorithms can be considered a special case. The course goes into more theoretical content on algorithm analysis than 15-122 and 15-150 while still including a significant programming component and covering a variety of practical applications such as problems in data analysis, graphics, text processing, and the computational sciences. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course. Register for Lecture 1. All students will be waitlisted for Lecture 2 until Lecture 1 is full.

Prerequisites: 15-150 Min. grade C and 15-122 Min. grade C

Course Website: <http://www.cs.cmu.edu/~15210/>

15-213 Introduction to Computer Systems

All Semesters: 12 units

This course provides a programmer's view of how computer systems execute programs, store information, and communicate. It enables students to become more effective programmers, especially in dealing with issues of performance, portability and robustness. It also serves as a foundation for courses on compilers, networks, operating systems, and computer architecture, where a deeper understanding of systems-level issues is required. Topics covered include: machine-level code and its generation by optimizing compilers, performance evaluation and optimization, computer arithmetic, memory organization and management, networking technology and protocols, and supporting concurrent computation. NOTE FOR GRADUATE STUDENTS: This course is not open to graduate students beginning Spring 2015. Graduate students must register for 15-513 instead. Prerequisite: 15-122 Min. grade C

Course Website: <https://www.cs.cmu.edu/~213/>**15-214 Principles of Software Construction: Objects, Design, and Concurrency**

Fall and Spring: 12 units

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, program structures, and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object oriented programming, (3) static and dynamic analysis for programs, and (4) concurrent and distributed software. Student assignments involve engagement with complex software such as distributed massively multi-player game systems and frameworks for graphical user interaction. Prerequisites: (15-121 Min. grade C or 15-122 Min. grade C) and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C)

15-217 Logic and Mechanized Reasoning

Fall: 9 units

Symbolic logic is fundamental to computer science, providing a foundation for the theory of programming languages, database theory, AI, knowledge representation, automated reasoning, interactive theorem proving, and formal verification. Formal methods based on logic complement statistical methods and machine learning by providing rules of inference and means of representation with precise semantics. These methods are central to hardware and software verification, and have also been used to solve open problems in mathematics. This course will introduce students to logic on three levels: theory, implementation, and application. It will focus specifically on applications to automated reasoning and interactive theorem proving. We will present the underlying mathematical theory, and students will develop the mathematical skills that are needed to design and reason about logical systems in a rigorous way. We will also show students how to represent logical objects in a functional programming language, Lean, and how to implement fundamental logical algorithms. We will show students how to use contemporary automated reasoning tools, including SAT solvers, SMT solvers, and first-order theorem provers to solve challenging problems. Finally, we will show students how to use Lean as an interactive theorem prover.

Prerequisites: (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and 15-150 Min. grade C

Course Website: <http://www.cs.cmu.edu/~mheule/15217-f21/>**15-236 Special Topics: Saving Humanity With Computational Models**

Intermittent: 9 units

We live in a complex society and on a complex planet; but we tend to think about the world through simplified models and assumptions. How do we know if our simplified mental models make sense? Computational modeling is an approach to understanding our understanding of the world wherein we write down our mental models as computer code, mix in a bit of real data, and run it to see what we can learn. Models can help us to understand ourselves, the world around us, and how to shape the future. This course will teach the basics of computational modeling through hands-on exercises investigating student-directed topics. We will cover the basics of computational modeling, finding and processing data, visualization, modularity, and interactivity. Students will build a series of models throughout the course, starting with smaller warm-ups and culminating in a final project in which students will work together to create a high-quality model and interactive web-based visualization with the goal of informing public discourse and policymaking. This course is designed for CS sophomores and most "seats" in the course will be reserved for CS sophomores.

Prerequisites: 15-112 Min. grade C and 21-120 Min. grade C

15-237 Special Topic: Cross-Platform Mobile Web Apps

Intermittent: 12 units

An introduction to writing cross-platform mobile web apps. Using a tool chain based on HTML5, CSS3, JavaScript, and a variety of supporting frameworks, we will write apps that are effectively designed both for desktop and mobile browsers, and which can be converted into native apps for Android, iOS, and Windows Phone 7 devices. Additional topics will include designing user interfaces for mobile devices, accessing mobile device APIs (such as accelerometer, GPS, compass, or camera), and power management issues. While this course focuses on browser-side technologies, we will briefly explore JavaScript-based server-side technologies (though students should consider 15-437 for extensive treatment of server-side topics). Note that we will not be writing native apps in Objective-C for iOS nor in Java for Android, though we may include some brief exposure to these technologies near the end of the course.

Prerequisite: 15-112 Min. grade C

15-251 Great Ideas in Theoretical Computer Science

Fall and Spring: 12 units

This course is about how to use theoretical ideas to formulate and solve problems in computer science. It integrates mathematical material with general problem solving techniques and computer science applications. Examples are drawn from algorithms, complexity theory, game theory, probability theory, graph theory, automata theory, algebra, cryptography, and combinatorics. Assignments involve both mathematical proofs and programming. NOTE: students must achieve a C or better in order to use this course to satisfy the pre-requisite for any subsequent Computer Science course.

Prerequisites: (15-150 Min. grade C or 15-122 Min. grade C) and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~15251/>**15-259 Probability and Computing**

Spring: 12 units

Probability theory is indispensable in computer science today. In areas such as artificial intelligence and computer science theory, probabilistic reasoning and randomization are central. Within networks and systems, probability is used to model uncertainty and queuing latency. This course gives an introduction to probability as it is used in computer science theory and practice, drawing on applications and current research developments as motivation. The course has 3 parts: Part I is an introduction to probability, including discrete and continuous random variables, heavy tails, simulation, Laplace transforms, z-transforms, and applications of generating functions. Part II is an in-depth coverage of concentration inequalities, like the Chernoff bound and SLLN bounds, as well as their use in randomized algorithms. Part III covers Markov chains (both discrete-time and continuous-time) and stochastic processes and their application to queuing systems performance modeling. This is a fast-paced class which will cover more material than the other probability options and will cover it in greater depth.

Prerequisites: (21-228 Min. grade C or 15-251 Min. grade C) and 21-259 Min. grade C and 21-241 Min. grade C

15-260 Statistics and Computing

Spring: 3 units

Statistics is essential for a wide range of fields including machine learning, artificial intelligence, bioinformatics, and finance. This mini course presents the fundamental concepts and methods in statistics in six lectures. The course covers key topics in statistical estimation, inference, and prediction. This course is only open to students enrolled in 15-259. Enrollment for 15-260, mini 4, starts around mid semester.

Prerequisites: 21-241 Min. grade C and 21-259 Min. grade C and 15-251 Min. grade C

15-281 Artificial Intelligence: Representation and Problem Solving

Fall and Spring: 12 units

This course is about the theory and practice of Artificial Intelligence. We will study modern techniques for computers to represent task-relevant information and make intelligent (i.e. satisficing or optimal) decisions towards the achievement of goals. The search and problem solving methods are applicable throughout a large range of industrial, civil, medical, financial, robotic, and information systems. We will investigate questions about AI systems such as: how to represent knowledge, how to effectively generate appropriate sequences of actions and how to search among alternatives to find optimal or near-optimal solutions. We will also explore how to deal with uncertainty in the world, how to learn from experience, and how to learn decision rules from data. We expect that by the end of the course students will have a thorough understanding of the algorithmic foundations of AI, how probability and AI are closely interrelated, and how automated agents learn. We also expect students to acquire a strong appreciation of the big-picture aspects of developing fully autonomous intelligent agents. Other lectures will introduce additional aspects of AI, including natural language processing, web-based search engines, industrial applications, autonomous robotics, and economic/game-theoretic decision making.

Prerequisites: 15-122 Min. grade C and (21-241 Min. grade C or 21-240 Min. grade C or 18-202 Min. grade C) and (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C)

Course Website: <https://www.cs.cmu.edu/~15281/>

15-282 Artificial Intelligence for Medicine

Intermittent: 9 units

This course introduces Artificial Intelligence (AI) and its recent applications in medicine for students with only a little background in computer science. It starts by motivating and defining AI, before folding over to a survey of some of its newest applications to medicine, including diagnosis, prognosis, drug discovery, and recommendations of individualized treatments, to mention just a few. Afterwards, it provides a birds-eye view of some of the major AI techniques, including machine learning, deep neural networks, recommendation systems, ranked retrieval, and probabilistic graphical models. Finally, it concludes with a discussion on some of the concerns related to AI, including ethical issues, job security, society, and healthcare institutions, among others. The course comprises a balance of lectures, case studies, live demonstrations of some medical AI applications, problem-solving and programming assignments, and research tasks. The students will be exposed to industry- and research-based perspectives on AI for medicine. In addition, they will learn through a course project the nuances of working with medical data and applying AI models to solve concrete problems in healthcare.

Prerequisite: 15-112 Min. grade C

15-288 Special Topic: Machine Learning in a Nutshell

Fall and Spring: 9 units

THIS COURSE RUNS IN CMU QATAR ONLY. This course is about the application of machine learning (ML) concepts and models to solve challenging real-world problems. The emphasis of the course is on the methodological and practical aspects of designing, implementing, and using ML solutions. Course topics develop around the notion of ML process pipeline, that identifies the multi-staged process of building and deploying an ML solution. An ML pipeline includes: definition of the problem, objectives, and performance metrics; collection and management of relevant operational data; data wrangling (transforming, cleaning, iterating, scaling); perform feature engineering on the available data in terms of feature selection, feature extraction, feature processing; selection of appropriate ML models based on problem requirements and available data; implementation, application, testing, and evaluation of the selected model(s); deployment of the final ML model. The course tackles all the stages of the ML pipeline, presenting conceptual insights and providing algorithmic and software tools to select and implement effective ways of proceeding and dealing with the challenges of the different stages.

Prerequisite: 15-112 Min. grade C

15-292 History of Computing

Spring: 5 units

This course traces the history of computational devices, pioneers and principles from the early ages through the present. Topics include early computational devices, mechanical computation in the 19th century, events that led to electronic computing advances in the 20th century, the advent of personal computing and the Internet, and the social, legal and ethical impact of modern computational artifacts. This course also includes a history of programming languages, operating systems, processors and computing platforms. Students should have an introductory exposure to programming prior to taking this course.

Prerequisites: (76-101 or 76-108 or 76-107 or 76-102 or 76-106) and (15-122 or 15-150 or 15-110 or 15-112)

15-294 Special Topic: Rapid Prototyping Technologies

Fall and Spring: 5 units

This mini-course introduces students to rapid prototyping technologies with a focus on laser cutting and 3D printing. The course has three components: 1) A survey of rapid prototyping and additive manufacturing technologies, the maker and open source movements, and societal impacts of these technologies; 2) An introduction to the computer science behind these technologies: CAD tools, file formats, slicing algorithms; 3) Hands-on experience with SolidWorks, laser cutting, and 3D printing, culminating in student projects (e.g. artistic creations, functional objects, replicas of famous calculating machines, etc.).

Prerequisites: 15-104 Min. grade C or 15-112 Min. grade C or 15-110 Min. grade C

Course Website: <https://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/15294-f21/>

15-295 Competition Programming II

Fall and Spring: 5 units

Each year, Carnegie Mellon fields several teams for participation in the ICPC Regional Programming Contest. During many recent years, one of those teams has earned the right to represent Carnegie Mellon at the ICPC World Finals. This course is a vehicle for those who consistently and rigorously train in preparation for the contests to earn course credit for their effort and achievement. Preparation involves the study of algorithms, the practice of programming and debugging, the development of test sets, and the growth of team, communication, and problem solving skills. Neither the course grade nor the number of units earned are dependent on ranking in any contest. Students are not required to earn course credit to participate in practices or to compete in ACM-ICPC events. Students who have not yet taken 15-295 should register for 15-195; only students who have already taken 15-295 should register for 15-295 again.

Prerequisites: (15-295 Min. grade C or 15-195 Min. grade C) and 15-122 Min. grade C

Course Website: <https://contest.cs.cmu.edu/295/>

15-300 SEE 07-300 Research and Innovation in Computer Science

Fall: 9 units

This Fall course is the first part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Course topics will include the following: an overview of important things to know about how research and innovation works in the field of computer science; a survey of the current cutting-edge of computer science research, both here at Carnegie Mellon and elsewhere; critical thinking skills when reading research publications that disagree with each other; strategies for coping with open-ended problems; and technical communication skills for computer scientists. Students will also match up with a faculty mentor for a potential Technology Innovation Project (to be performed in the Spring), put together a detailed plan of attack for that project, and start to get up to speed (including background reading, etc.). This course can be used to satisfy the Technical Communications requirement for the CS major.

Prerequisites: (76-101 Min. grade C and 15-210 Min. grade C and 15-213 Min. grade C) or (76-101 Min. grade C and 15-213 Min. grade C and 15-251 Min. grade C) or (15-210 Min. grade C and 15-251 Min. grade C and 76-101 Min. grade C)

15-312 Foundations of Programming Languages

Fall and Spring: 12 units

This course discusses in depth many of the concepts underlying the design, definition, implementation, and use of modern programming languages. Formal approaches to defining the syntax and semantics are used to describe the fundamental concepts underlying programming languages. A variety of programming paradigms are covered such as imperative, functional, logic, and concurrent programming. In addition to the formal studies, experience with programming in the languages is used to illustrate how different design goals can lead to radically different languages and models of computation.

Prerequisites: 15-150 Min. grade C and (15-251 Min. grade C or 21-228 Min. grade C)

15-313 Foundations of Software Engineering

Fall: 12 units

Students gain exposure to the fundamentals of modern software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software. Topics related to software artifacts include design models, patterns, coding, static and dynamic analysis, testing and inspection, measurement, and software architecture and frameworks. Topics related to software process include modeling, requirements engineering, process models and evaluation, team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, and will include both written and programming assignments. Students will get experience with modern software engineering tools.

Prerequisite: 15-214

15-314 Programming Language Semantics

Spring: 12 units

This lecture course introduces the foundational concepts and techniques of programming language semantics. The aim is to demonstrate the utility of a scientific approach, based on mathematics and logic, with applications to program analysis, language design, and compiler correctness. We focus on the most widely applicable frameworks for semantic description: denotational, operational, and axiomatic semantics. We use semantics to analyze program behavior, guide the development of correct programs, prove correctness of a compiler, validate logics for program correctness, and derive general laws of program equivalence. We will discuss imperative and functional languages, sequential and parallel, as time permits.

Prerequisites: 15-251 Min. grade C and 15-150 Min. grade C

15-316 Software Foundations of Security and Privacy

Fall: 9 units

Security and privacy issues in computer systems continue to be a pervasive issue in technology and society. Understanding the security and privacy needs of software, and being able to rigorously demonstrate that those needs are met, is key to eliminating vulnerabilities that cause these issues. Students who take this course will learn the principles needed to make these assurances about software, and some of the key strategies used to make sure that they are correctly implemented in practice. Topics include: policy models and mechanisms for confidentiality, integrity, and availability, language-based techniques for detecting and preventing security threats, mechanisms for enforcing privacy guarantees, and the interaction between software and underlying systems that can give rise to practical security threats. Students will also gain experience applying many of these techniques to write code that is secure by construction.

Prerequisite: 15-213 Min. grade C

15-317 Constructive Logic

Fall and Spring: 9 units

This multidisciplinary junior-level course is designed to provide a thorough introduction to modern constructive logic, its roots in philosophy, its numerous applications in computer science, and its mathematical properties. Some of the topics to be covered are intuitionistic logic, inductive definitions, functional programming, type theory, realizability, connections between classical and constructive logic, decidable classes.

Prerequisite: 15-150 Min. grade C

Course Website: <https://lfcps.org/course/constlog.html>**15-319 Cloud Computing**

Fall and Spring: 12 units

This course gives students an overview of Cloud Computing, which is the delivery of computing as a service over a network, whereby distributed resources are rented, rather than owned, by an end user as a utility. Students will study its enabling technologies, building blocks, and gain hands-on experience through projects utilizing public cloud infrastructures. Cloud computing services are widely adopted by many organizations across domains. The course will introduce the cloud and cover the topics of data centers, software stack, virtualization, software defined networks and storage, cloud storage, and programming models. We will start by discussing the clouds motivating factors, benefits, challenges, service models, SLAs and security. We will describe several concepts behind data center design and management, which enable the economic and technological benefits of the cloud paradigm. Next, we will study how CPU, memory and I/O resources, network (SDN) and storage (SDS) are virtualized, and the key role of virtualization to enable the cloud. Subsequently, students will study cloud storage concepts like data distribution, durability, consistency and redundancy. We will discuss distributed file systems, NoSQL databases and object storage using HDFS, CephFS, HBASE, MongoDB, Cassandra, DynamoDB, S3, and Swift as case studies. Finally, students will study the MapReduce, Spark and GraphLab programming models. Students will work with Amazon Web Services and Microsoft Azure, to rent and provision compute resources and then program and deploy applications using these resources. Students will develop and evaluate scaling and load balancing solutions, work with cloud storage systems, and develop applications in several programming paradigms. 15619 students must complete an extra team project which entails designing and implementing a cost- and performance-sensitive web-service for querying big data.

Prerequisite: 15-213 Min. grade C

Course Website: <https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing/> (<https://csd.cs.cmu.edu/course-profiles/15-319-619-Cloud-Computing/>)

15-322 Introduction to Computer Music

Spring: 9 units

Computers are used to synthesize sound, process signals, and compose music. Personal computers have replaced studios full of sound recording and processing equipment, completing a revolution that began with recording and electronics. In this course, students will learn the fundamentals of digital audio, basic sound synthesis algorithms, and techniques for digital audio effects and processing. Students will apply their knowledge in programming assignments using a very high-level programming language for sound synthesis and composition. In a final project, students will demonstrate their mastery of tools and techniques through music composition or by the implementation of a significant sound-processing technique.

Prerequisites: 15-122 Min. grade C or 15-112 Min. grade C

Course Website: <https://courses.ideate.cmu.edu/15-322> (<https://courses.ideate.cmu.edu/15-322/>)

15-323 Computer Music Systems and Information Processing

Spring: 9 units

This course presents concepts and techniques for representing and manipulating discrete music information, both in real time and off line. Representations of music as explicitly timed event sequences will be introduced, and students will learn how to build efficient run-time systems for event scheduling, tempo control, and interactive processing. The MIDI protocol is used to capture real-time performance information and to generate sound. The course will also cover non-real-time processing of music data, including Markov models, style recognition, computer accompaniment, query-by-humming, and algorithmic composition. This course is independent of, and complementary to 15-322, Introduction to Computer Music, which focuses on sound synthesis and signal processing.

Prerequisite: 15-122 Min. grade C

15-326 Computational Microeconomics

Intermittent: 9 units

Use of computational techniques to operationalize basic concepts from economics. Expressive marketplaces: combinatorial auctions and exchanges, winner determination problem. Game theory: normal and extensive-form games, equilibrium notions, computing equilibria. Mechanism design: auction theory, automated mechanism design. Prerequisites: (21-128 Min. grade C or 21-127 Min. grade C or 15-151 Min. grade C or 80-210 or 80-211 Min. grade C) and (21-235 or 36-218 or 36-235 or 36-225)

15-327 Monte Carlo Methods and Applications

Fall: 9 units

The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language.

Prerequisites: (21-254 Min. grade C or 21-259 Min. grade C or 21-268 Min. grade C or 21-269 Min. grade C or 21-256 Min. grade C or 21-266 Min. grade C) and (36-235 Min. grade C or 36-225 Min. grade C or 36-219 Min. grade C or 18-465 Min. grade C or 36-218 Min. grade C or 21-325 Min. grade C or 15-259 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~mcrane/random/>

15-330 Introduction to Computer Security

Fall and Spring: 12 units

Security is becoming one of the core requirements in the design of critical systems. This course will introduce students to the intro-level fundamental knowledge of computer security and applied cryptography. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.

Prerequisite: 15-213 Min. grade C

Course Website: <https://www.andrew.cmu.edu/course/18-330/>

15-346 Computer Architecture: Design and Simulation

Intermittent: 12 units

This course will help students develop an understanding of basic microarchitectural principles and designs. Starting with creating benchmarks and simulators, students will learn the practice of computer architecture design. The emphasis will be on how processors exploit instruction-level parallelism for performance, as well as the supporting technologies such as caches and branch prediction that are required. Several frontiers of current research will be explored in energy efficiency and security threats.

Prerequisite: 15-213 Min. grade C

15-348 Embedded Systems

Spring: 9 units

This course is offered only at Carnegie Mellon's campus in Qatar. This course covers the broad range of foundational skills that apply across all embedded computer system application areas, from thermostats to self-driving vehicles. The emphasis is at the layer where hardware meets software. Topics include microcontroller hardware, assembly language, embedded C programming, analog I/O, timers, code optimization, interrupts, and concurrency. Real world engineering practices, constraints, and example applications are integrated throughout the course. Weekly hands-on hardware and software experiences with an industry-strength automotive embedded controller are coordinated with the lecture content to reinforce core skills.

Prerequisite: 15-122 Min. grade C

15-349 Introduction to Computer and Network Security

Fall: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. This course is meant to offer Computer Science undergraduate students in their junior or senior year a broad overview of the field of computer security. Students will learn the basic concepts in computer security including software vulnerability analysis and defense, networking and wireless security, applied cryptography, as well as ethical, legal, social and economic facets of security. Students will also learn the fundamental methodology for how to design and analyze security critical systems.

Prerequisite: 15-122

15-351 Algorithms and Advanced Data Structures

Fall and Spring: 12 units

The objective of this course is to study algorithms for general computational problems, with a focus on the principles used to design those algorithms. Efficient data structures will be discussed to support these algorithmic concepts. Topics include: Run time analysis, divide-and-conquer algorithms, dynamic programming algorithms, network flow algorithms, linear and integer programming, large-scale search algorithms and heuristics, efficient data storage and query, and NP-completeness. Although this course may have a few programming assignments, it is primarily not a programming course. Instead, it will focus on the design and analysis of algorithms for general classes of problems. This course is not open to CS graduate students who should consider taking 15-651 instead. THIS COURSE IS NOT OPEN TO COMPUTER SCIENCE MAJORS OR MINORS.

Prerequisites: 15-121 or 15-122

Course Website: <https://www.csd.cs.cmu.edu/course-profiles/15-351-Algorithms-and-Advanced-Data-Structures> (<https://www.csd.cs.cmu.edu/course-profiles/15-351-Algorithms-and-Advanced-Data-Structures/>)

15-354 Computational Discrete Mathematics

Fall: 12 units

This course is about the computational aspects of some of the standard concepts of discrete mathematics (relations, functions, logic, graphs, algebra, automata), with emphasis on efficient algorithms. We begin with a brief introduction to computability and computational complexity. Other topics include: iteration, orbits and fixed points, order and equivalence relations, propositional logic and satisfiability testing, finite fields and shift register sequences, finite state machines, and cellular automata. Computational support for some of the material is available in the form of a Mathematica package.

Prerequisites: 15-251 Min. grade C or 21-228 Min. grade C

Course Website: <http://www.cs.cmu.edu/~cdm/>

15-355 Modern Computer Algebra

Spring: 9 units

The goal of this course is to investigate the relationship between algebra and computation. The course is designed to expose students to algorithms used for symbolic computation, as well as to the concepts from modern algebra which are applied to the development of these algorithms. This course provides a hands-on introduction to many of the most important ideas used in symbolic mathematical computation, which involves solving system of polynomial equations (via Groebner bases), analytic integration, and solving linear difference equations. Throughout the course the computer algebra system Mathematica will be used for computation.

Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

Course Website: <http://www.andrew.cmu.edu/course/15-355/>

15-356 Introduction to Cryptography

Spring: 12 units

This course is aimed as an introduction to modern cryptography. This course will be a mix of applied and theoretical cryptography. We will cover popular primitives such as: pseudorandom functions, encryption, signatures, zero-knowledge proofs, multi-party computation, and Blockchains. In addition, we will cover the necessary number-theoretic background. We will cover formal definitions of security, as well as constructions based on well established assumptions like factoring. Please see the course webpage for a detailed list of topics.

Prerequisites: 15-251 Min. grade C or 21-228

Course Website: <http://www.cs.cmu.edu/~goyal/15356/>

15-359 Probability and Computing

Intermittent: 12 units

Probability theory has become indispensable in computer science. In areas such as artificial intelligence and computer science theory, probabilistic methods and ideas based on randomization are central. In other areas such as networks and systems, probability is becoming an increasingly useful framework for handling uncertainty and modeling the patterns of data that occur in complex systems. This course gives an introduction to probability as it is used in computer science theory and practice, drawing on applications and current research developments as motivation and context. Topics include combinatorial probability and random graphs, heavy tail distributions, concentration inequalities, various randomized algorithms, sampling random variables and computer simulation, and Markov chains and their many applications, from Web search engines to models of network protocols. The course will assume familiarity with 3-D calculus and linear algebra.

Prerequisites: 21-241 and 21-259 and 15-251 Min. grade C

Course Website: <http://www.cs.cmu.edu/~harchol/15359/class.html>

15-365 Experimental Animation

Intermittent: 12 units

This class will explore animation from the student's perspective with a sense of investigation toward both form and content. Topics in the class will include non-linear narrative, visual music, puppet and non-traditional materials, manipulation of motion and performance capture data, immersive environments.

Prerequisite: 15-213 Min. grade C

15-367 Algorithmic Textiles Design

Intermittent: 12 units

Textile artifacts are and #8212; quite literally and #8212; all around us; from clothing to carpets to car seats. These items are often produced by sophisticated, computer-controlled fabrication machinery. In this course we will discuss everywhere code touches textiles fabrication, including design tools, simulators, and machine control languages. Students will work on a series of multi-week, open-ended projects, where they use code to create patterns for modern sewing/embroidery, weaving, and knitting machines; and then fabricate these patterns in the textiles lab. Students in the 800-level version of the course will additionally be required to create a final project that develops a new algorithm, device, or technique in textiles fabrication.

Course Website: <http://graphics.cs.cmu.edu/courses/15-869K-s21/>**15-369 Special Topics: Perceptual Computing**

Intermittent: 9 units

This course is ONLY offered at Carnegie Mellon in Qatar. What can today's computers see, hear, and feel? This project-based course is designed to provide students exposure to the state-of-the-art in machine perception and the algorithms behind them. Student groups will design a perceptual computing project around Intel's Creative Camera or Microsoft's Kinect. Students will learn to use tools in face detection and recognition, hand and finger tracking, and speech recognition, along with algorithms to make decisions based on these input modalities.

Prerequisites: 15-122 and 21-241

15-382 Collective Intelligence

Spring: 9 units

This course is about the study of distributed control and intelligence systems involving a large number of autonomous components that interact with each other, dynamically adapting to their changing environment as a result of mutual interactions. Examples of such components include cars in city traffic, pedestrians moving in crowds, firms competing in a market, ants foraging for food, or mobile robots in a swarm or multi-robot system. Under certain conditions, such systems can produce useful system-level behaviors, display self-organized spatial-temporal patterns, effectively perform computations, information dissemination, and decision-making. Loosely speaking, when this happens we can say that the system is displaying a form of "collective intelligence". Collective intelligence will expose students to relevant mathematical and computational models from following fields and domains: Cellular automata and Random boolean networks, Social choice, Game theory, Distributed consensus, Task allocation, Swarm intelligence, Social networks, Pattern formation, and Self-organizing maps. The course will also help bridge the gap between theory and practice via assignments where students will implement system models and explore their properties in application domains of practical interest.

Prerequisite: 15-122 Min. grade C

15-383 Introduction to Text Processing

Fall: 6 units

Text processing is a mini-course about text basic techniques of processing human language in text format. The course has theoretical and hands-on components. In the theoretical component, the course will discuss challenges in processing human languages, and review the basics of statistics and probability theory and their application to language problems. In the hands-on part, students will learn about Python programming and use it to process large volumes of text using various techniques. The processing will range from simple steps such as tokenization and part-of-speech tagging to full-fledged applications such as statistical machine translation, search and document/topic classification. The course is suited for junior and senior students in CS and IS.

Prerequisites: 15-122 Min. grade C or 15-121 Min. grade C

15-385 Introduction to Computer Vision

Spring: 6 units

An introduction to the science and engineering of computer vision, i.e. the analysis of the patterns in visual images with the view to understanding the objects and processes in the world that generate them. Major topics include image formation and sensing, fourier analysis, edge and contour detection, inference of depth, shape and motion, classification, recognition, tracking, and active vision. The emphasis is on the learning of fundamental mathematical concepts and techniques and applying them to solve real vision problems. The discussion will also include comparison with human and animal vision from psychological and biological perspectives. Students will learn to think mathematically and develop skills in translating ideas and mathematical thoughts into programs to solve real vision problems.

Prerequisites: 15-122 Min. grade C and 21-241

15-386 Neural Computation

Spring: 9 units

Computational neuroscience is an interdisciplinary science that seeks to understand how the brain computes to achieve natural intelligence. It seeks to understand the computational principles and mechanisms of intelligent behaviors and mental abilities and #8212; such as perception, language, motor control, and learning and #8212; by building artificial systems and computational models with the same capabilities. This course explores how neurons encode and process information, adapt and learn, communicate, cooperate, compete and compute at the individual level as well as at the levels of networks and systems. It will introduce basic concepts in computational modeling, information theory, signal processing, system analysis, statistical and probabilistic inference. Concrete examples will be drawn from the visual system and the motor systems, and studied from computational, psychological and biological perspectives. Students will learn to perform computational experiments using Matlab and quantitative studies of neurons and neuronal networks.

Prerequisites: (15-112 Min. grade C or 15-122 Min. grade C) and 21-122

15-387 Computational Perception

Fall and Spring: 9 units

In this course, we will first cover the biological and psychological foundational knowledge of biological perceptual systems, and then apply computational thinking to investigate the principles and mechanisms underlying natural perception. The course will focus on vision this year, but will also touch upon other sensory modalities. You will learn how to reason scientifically and computationally about problems and issues in perception, how to extract the essential computational properties of those abstract ideas, and finally how to convert these into explicit mathematical models and computational algorithms. Topics include perceptual representation and inference, perceptual organization, perceptual constancy, object recognition, learning and scene analysis. Prerequisites: First year college calculus, some basic knowledge of linear algebra and probability and some programming experience are desirable.

Prerequisites: 21-122 and 15-112 Min. grade C and 21-241

15-388 Practical Data Science

Intermittent: 9 units

Data science is the study and practice of how we can extract insight and knowledge from large amounts of data. This course provides a practical introduction to the "full stack" of data science analysis, including data collection and processing, data visualization and presentation, statistical model building using machine learning, and big data techniques for scaling these methods. Topics covered include: collecting and processing data using relational methods, time series approaches, graph and network models, free text analysis, and spatial geographic methods; analyzing the data using a variety of statistical and machine learning methods include linear and non-linear regression and classification, unsupervised learning and anomaly detection, plus advanced machine learning methods like kernel approaches, boosting, or deep learning; visualizing and presenting data, particularly focusing the case of high-dimensional data; and applying these methods to big data settings, where multiple machines and distributed computation are needed to fully leverage the data. Students will complete weekly programming homework that emphasize practical understanding of the methods described in the course. In addition, students will develop a tutorial on an advanced topic, and will complete a group project that applies these data science techniques to a practical application chosen by the team; these two longer assignments will be done in lieu of a midterm or final.

Prerequisites: 15-112 Min. grade C or 15-122 Min. grade C

Course Website: <http://www.datasciencecourse.org>

15-390 Entrepreneurship for Computer Science

Fall: 9 units

This course is designed to develop skills related to entrepreneurship and innovation for non-business undergraduate and graduate students in the School of Computer Science. The course assumes no background courses in business and is appropriate for those who are interested in bringing innovations to market either through new companies or existing companies. The course provides an overview of entrepreneurship and innovation, develops an entrepreneurial frame of mind, and provides a framework for learning the rudiments of how to generate ideas. Students come up with or are presented with potential ideas and learn how to develop these ideas into opportunities, and to explore their potential for becoming viable businesses. They learn how to do market research, to develop go-to-market strategies, value propositions and to differentiate their products or services from potential competitors. The focus is on understanding and developing strategies for approaching the key elements of the entrepreneurial process...opportunity, resources and team. The course consists of a balance of lectures, case studies and encounters with entrepreneurs, investors and business professionals. The students are exposed to financial and intellectual property issues, and encounter a real world perspective on entrepreneurship, innovation and leadership. The output of the course is a mini-business plan or venture opportunity screening document that can be developed into a business plan in a subsequent course entitled New Venture Creation or through independent study.

Prerequisite: 15-112 Min. grade C

15-392 Special Topic: Secure Programming

Spring: 9 units

This course provides a detailed explanation of common programming errors in C and C++ and describes how these errors can lead to software systems that are vulnerable to exploitation. The course concentrates on security issues intrinsic to the C and C++ programming languages and associated libraries. It does not emphasize security issues involving interactions with external systems such as databases and web servers, as these are rich topics on their own. Topics to be covered include the secure and insecure use of integers, arrays, strings, dynamic memory, formatted input/output functions, and file I/O.

Prerequisite: 15-213 Min. grade C

Course Website: <https://www.securecoding.cert.org/confluence/display/sci/15392+Secure+Programming> (<https://www.securecoding.cert.org/confluence/display/sci/15392+Secure+Programming/>)

15-394 Intermediate Rapid Prototyping

Fall and Spring: 5 units

This course covers additional topics in rapid prototyping beyond the content of 15-294. Example topics include mechanism design, procedural shape generation using Grasshopper, 3D scanning and mesh manipulation, and advanced SolidWorks concepts. The only prerequisite is basic familiarity with SolidWorks, which can be obtained via 15-294, from other CMU courses, or from online tutorials.

Course Website: <https://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/15394-f21/>

15-400 SEE 07-400 Research Practicum in Computer Science

Spring: 12 units

This Spring course is the second part of a two-course sequence that is designed to help prepare students to invent the future state-of-the-art in the field of computer science. Building directly upon 15-300 (the prerequisite for this course), students will conduct a semester-long independent research project, under the guidance of both the course staff and a faculty project mentor. The course does not meet for lecture or recitations. Instead, the students will spend their time working on their research projects, and will also meet with course staff on a bi-weekly basis to discuss their progress. Students will prepare a written report and a poster presentation at the end of the semester to describe what they have accomplished.

Prerequisite: 15-300 Min. grade C

15-405 Engineering Distributed Systems

Spring: 9 units

This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programming. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.

Prerequisite: 15-410 Min. grade B

15-410 Operating System Design and Implementation

Fall and Spring: 15 units

Operating System Design and Implementation is a rigorous hands-on introduction to the principles and practice of operating systems. The core experience is writing a small Unix-inspired OS kernel, in C with some x86 assembly language, which runs on a PC hardware simulator (and on actual PC hardware if you wish). Work is done in two-person teams, and "team programming" skills (source control, modularity, documentation) are emphasized. The size and scope of the programming assignments typically result in students significantly developing their design, implementation, and debugging abilities. Core concepts include the process model, virtual memory, threads, synchronization, and deadlock; the course also surveys higher-level OS topics including file systems, interprocess communication, networking, and security. Students, especially graduate students, who have not satisfied the prerequisite at Carnegie Mellon are strongly cautioned - to enter the class you must be able to write a storage allocator in C, use a debugger, understand 2's-complement arithmetic, and translate between C and x86 assembly language. The instructor may require you to complete a skills assessment exercise before the first week of the semester in order to remain registered in the class. Auditing: this course is usually full, and we generally receive many more requests to audit than we can accept. If you wish to audit, please have your advisor contact us before the semester begins to discuss your educational goals.

Prerequisite: 15-213 Min. grade C

Course Website: https://www.csd.cs.cmu.edu/course-profiles/15-410_605-Operating-System-Design-and-Implementation (https://www.csd.cs.cmu.edu/course-profiles/15-410_605-Operating-System-Design-and-Implementation/)

15-411 Compiler Design

Spring: 15 units

This course covers the design and implementation of compiler and run-time systems for high-level languages, and examines the interaction between language design, compiler design, and run-time organization. Topics covered include syntactic and lexical analysis, handling of user-defined types and type-checking, context analysis, code generation and optimization, and memory management and run-time organization.

Prerequisite: 15-213 Min. grade C

Course Website: https://csd.cs.cmu.edu/course-profiles/15-411_611-compiler-design (https://csd.cs.cmu.edu/course-profiles/15-411_611-compiler-design/)

15-412 Operating System Practicum

Fall

The goal of this class is for students to acquire hands-on experience with operating-system code as it is developed and deployed in the real world. Groups of two to four students will select, build, install, and become familiar with an open-source operating system project; propose a significant extension or upgrade to that project; and develop a production-quality implementation meeting the coding standards of that project. Unless infeasible, the results will be submitted to the project for inclusion in the code base. Variations on this theme are possible at the discretion of the instructor. For example, it may be possible to work within the context of a non-operating-system software infrastructure project (window system, web server, or embedded network device kernel) or to extend a 15-410 student kernel. In some situations students may work alone. Group membership and unit count (9 units versus 12) will be decided by the third week of the semester. Contributing to a real-world project will involve engaging in some mixture of messy, potentially open-ended activities such as: learning a revision control system, writing a short design document, creating and updating a simple project plan, participating in an informal code review, synthesizing scattered information about hardware and software, classifying and/or reading large amounts of code written by various people over a long period of time, etc.

Prerequisite: 15-410

15-413 SEE 17-413 Software Engineering Practicum

Spring: 12 units

CHANGED TO 17-413 STARTING SPRING 2018. This course is a project-based course in which students conduct a semester-long project for a real client in small teams. The project defines real world needs for the client in their company. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Teams will give presentations and deliver documents on topics such as: risk management project planning requirements architecture detailed design quality assurance final product presentations reflections on the experience Evaluation will be based on the in-class presentations, process and project documentation, how well the teams follow software engineering (SE) practices, and the client's satisfaction with the product. Individual grades will be influenced by peer reviews, individual reflection documents, mentor impressions, and presentation performance. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. They will have teamwork, process, and product skills to support immediate competency in a software engineering organization, along with a deeper understanding that prepares them to evaluate the new processes and techniques they will encounter in the workplace.

15-414 Bug Catching: Automated Program Verification

Spring: 9 units

Many CS and ECE students will be developing software and hardware that must be ultra reliable at some point in their careers. Logical errors in such designs can be costly, even life threatening. There have already been a number of well publicized errors like the Intel Pentium floating point error and the Ariane 5 crash. In this course we will study tools for finding and preventing logical errors. Three types of tools will be studied: automated theorem proving, state exploration techniques like model checking and tools based on static program analysis. Although students will learn the theoretical basis for such tools, the emphasis will be on actually using them on real examples. This course can be used to satisfy the Logic and amp; Languages requirement for the Computer Science major.

Prerequisites: 15-122 Min. grade C and 15-251 Min. grade C

Course Website: <http://www.cs.cmu.edu/~15414/>**15-415 Database Applications**

Fall: 12 units

This course covers the fundamental topics for Database Management Systems: Database System Architectural Principles (ACID properties; data abstraction; external, conceptual, and internal schemata; data independence; data definition and data manipulation languages), Data models (entity-relationship and relational data models; data structures, integrity constraints, and operations for each data model; relational query languages: SQL, algebra, calculus), Theory of database design (functional dependencies; normal forms; dependency preservation; information loss), Query Optimization (equivalence of expressions, algebraic manipulation; optimization of selections and joins), Storage Strategies (indices, B-trees, hashing), Query Processing (execution of sort, join, and aggregation operators), and Transaction Processing (recovery and concurrency control).

Prerequisites: 15-213 Min. grade C and 15-210 Min. grade C

Course Website: <http://15415.courses.cs.cmu.edu/>**15-417 HOT Compilation**

Intermittent: 12 units

The course covers the implementation of compilers for higher-order, typed languages such as ML and Haskell, and gives an introduction to type-preserving compilation. Topics covered include type inference, elaboration, CPS conversion, closure conversion, garbage collection, phase splitting, and typed assembly language.

Prerequisites: 15-312 or 15-317

Course Website: <https://www.cs.cmu.edu/~crary/hot/>**15-418 Parallel Computer Architecture and Programming**

Fall and Spring: 12 units

The fundamental principles and engineering tradeoffs involved in designing modern parallel computers, as well as the programming techniques to effectively utilize these machines. Topics include naming shared data, synchronizing threads, and the latency and bandwidth associated with communication. Case studies on shared-memory, message-passing, data-parallel and dataflow machines will be used to illustrate these techniques and tradeoffs. Programming assignments will be performed on one or more commercial multiprocessors, and there will be a significant course project.

Prerequisite: 15-213 Min. grade C

Course Website: <http://15418.courses.cs.cmu.edu>**15-421 Information Security and Privacy**

Fall: 12 units

As layers upon layers of technology mediate our activities, issues of information security and privacy are becoming increasingly pervasive and complex. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of robust computer and information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile computing, the Internet of Things, social networking and digital currencies. Topics Covered: Information Security and Privacy: the big picture; A gentle introduction to cryptography; Certificates, PKI, Decentralized Trust Management; Authentication; Internet Security protocols; Risk management; Trusted Computing; Systems security; Web attacks; Cybercrime; Understanding the cyber security legal landscape; Information Privacy: Fundamental concepts and amp; legal landscape; Privacy and Big Data; Privacy Enhancing Technologies; Privacy Engineering; Usable Security and Privacy; Electronic payments and digital currencies; Emerging Security and Privacy challenges (e.g. Cloud Security and Privacy, Mobile and IoT Security and Privacy, Social Networking Security and Privacy)

Prerequisites: 15-112 and 76-101

Course Website: <http://www.normsadeh.com/isp-content> (<http://www.normsadeh.com/isp-content/>)**15-423 Special Topic: Digital Signal Processing for Computer Science**

Spring: 12 units

Digital signals comprise a large fraction of the data analyzed by computer scientists. Sound, e.g. speech and music, images, radar and many other signal types that were conventionally considered to be the domain of the Electrical engineer are now also in the domain of computer scientists, who must analyze them, make inferences, and develop machine learning techniques to analyze, classify and reconstruct such data. In this course we will cover the basics of Digital Signal Processing. We will concentrate on the basic mathematical formulations, rather than in-depth implementation details. We will cover the breadth of topics, beginning with the basics of signals and their representations, the theory of sampling, important transform representations, key processing techniques, and spectral estimation.

Prerequisites: (15-122 Min. grade C or 15-112 Min. grade C) and (36-217 or 36-625 or 21-325 or 15-359 or 36-225)

15-424 Logical Foundations of Cyber-Physical Systems

Intermittent: 12 units

Cyber-physical systems (CPSs) combine cyber capabilities (computation and/or communication) with physical capabilities (motion or other physical processes). Cars, aircraft, and robots are prime examples, because they move physically in space in a way that is determined by discrete computerized control algorithms. Designing these algorithms to control CPSs is challenging due to their tight coupling with physical behavior. At the same time, it is vital that these algorithms be correct, since we rely on CPSs for safety-critical tasks like keeping aircraft from colliding. This course pursues the fundamental question: "How can we provide people with cyber-physical systems they can bet their lives on?"

Prerequisites: 15-122 Min. grade C and 21-120 Min. grade C

Course Website: <http://lfcps.org/course/lfcps.html>

15-435 Foundations of Blockchains

Fall: 12 units

In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is cross-listed with 15-635. Undergraduates should enroll in 15-435. Graduates students should enroll in 15-635.

Prerequisites: 15-210 Min. grade C or 15-251 Min. grade C or 15-330

15-437 Web Application Development

Fall and Spring: 12 units

This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, XML, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must have programming and software design experience equivalent to about a typical Junior CS major and #8212;a sequence of three college CS courses or more. Python-specific experience is not necessary. Students must provide their own computer hardware for this course. Please see the Related URL above for more information.

Prerequisite: 15-214

15-439 Special Topics: Blockchains and Cryptocurrencies

Intermittent: 12 units

Introduction to Blockchains and Cryptocurrencies. We focus on the cryptographic and mathematical foundations of Blockchains. The course will start from the basics and will cover the latest research in this area towards the end.

15-440 Distributed Systems

Fall and Spring: 12 units

The goals of this course are twofold: First, for students to gain an understanding of the principles and techniques behind the design of distributed systems, such as locking, concurrency, scheduling, and communication across the network. Second, for students to gain practical experience designing, implementing, and debugging real distributed systems. The major themes this course will teach include scarcity, scheduling, concurrency and concurrent programming, naming, abstraction and modularity, imperfect communication and other types of failure, protection from accidental and malicious harm, optimism, and the use of instrumentation and monitoring and debugging tools in problem solving. As the creation and management of software systems is a fundamental goal of any undergraduate systems course, students will design, implement, and debug large programming projects. As a consequence, competency in both the C and Java programming languages is required.

Prerequisite: 15-213 Min. grade C

Course Website: <https://www.synergylabs.org/courses/15-440/>**15-441 Networking and the Internet**

Fall: 12 units

The emphasis in this course will be on the basic performance and engineering trade-offs in the design and implementation of computer networks. To make the issues more concrete, the class includes several multi-week projects requiring significant design and implementation. The goal is for students to learn not only what computer networks are and how they work today, but also why they are designed the way they are and how they are likely to evolve in the future. We will draw examples primarily from the Internet. Topics to be covered include: network architecture, routing, congestion/flow/error control, naming and addressing, peer-to-peer and the web, internetworking, and network security.

Prerequisite: 15-213 Min. grade C

15-445 Database Systems

Fall: 12 units

This course is on the design and implementation of database management systems. Topics include data models (relational, document, key/value), storage models (n-ary, decomposition), query languages (SQL, stored procedures), storage architectures (heaps, log-structured), indexing (order preserving trees, hash tables), transaction processing (ACID, concurrency control), recovery (logging, checkpoints), query processing (joins, sorting, aggregation, optimization), and parallel architectures (multi-core, distributed). Case studies on open-source and commercial database systems will be used to illustrate these techniques and trade-offs. The course is appropriate for students with strong systems programming skills.

Prerequisite: 15-213 Min. grade C

Course Website: <http://15445.courses.cs.cmu.edu>**15-449 Engineering Distributed Systems**

Spring: 9 units

This is a course for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programming. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. If you do not have the 15-410 prerequisite you will need to get approval from the faculty.

Prerequisite: 15-410 Min. grade B

15-451 Algorithm Design and Analysis

Fall and Spring: 12 units

This course is about the design and analysis of algorithms. We study specific algorithms for a variety of problems, as well as general design and analysis techniques. Specific topics include searching, sorting, algorithms for graph problems, efficient data structures, lower bounds and NP-completeness. A variety of other topics may be covered at the discretion of the instructor. These include parallel algorithms, randomized algorithms, geometric algorithms, low level techniques for efficient programming, cryptography, and cryptographic protocols.

Prerequisites: 15-210 Min. grade C and 21-241 Min. grade C and (21-228 Min. grade C or 15-251 Min. grade C)

Course Website: <https://www.csd.cs.cmu.edu/course-profiles/15-451-Algorithm-Design-and-Analysis> (<https://www.csd.cs.cmu.edu/course-profiles/15-451-Algorithm-Design-and-Analysis/>)**15-453 Formal Languages, Automata, and Computability**

Intermittent: 9 units

An introduction to the fundamental ideas and models underlying computing: finite automata, regular sets, pushdown automata, context-free grammars, Turing machines, undecidability, and complexity theory.

Prerequisites: 21-228 Min. grade C or 15-251 Min. grade C

15-455 Undergraduate Complexity Theory

Fall and Spring: 9 units

Complexity theory is the study of how much of a resource (such as time, space, parallelism, or randomness) is required to perform some of the computations that interest us the most. In a standard algorithms course, one concentrates on giving resource efficient methods to solve interesting problems. In this course, we concentrate on techniques that prove or suggest that there are no efficient methods to solve many important problems. We will develop the theory of various complexity classes, such as P, NP, co-NP, PH, #P, PSPACE, NC, AC, L, NL, UP, RP, BPP, IP, and PCP. We will study techniques to classify problems according to our available taxonomy. By developing a subtle pattern of reductions between classes we will suggest an (as yet unproven!) picture of how by using limited amounts of various resources, we limit our computational power.

Prerequisite: 15-251 Min. grade C

15-456 Computational Geometry

Intermittent: 9 units

How do you sort points in space? What does it even mean? This course takes the ideas of a traditional algorithms course, sorting, searching, selecting, graphs, and optimization, and extends them to problems on geometric inputs. We will cover many classical geometric constructions and novel algorithmic methods. Some of the topics to be covered are convex hulls, Delaunay triangulations, graph drawing, point location, geometric medians, polytopes, configuration spaces, linear programming, and others. This course is a natural extension to 15-451, for those who want to learn about algorithmic problems in higher dimensions.

Prerequisite: 15-451 Min. grade C

15-457 Special Topics in Theory: Advanced Algorithms

Intermittent: 12 units

Selected advanced topics in algorithms and computational theory. Topics vary from semester to semester.

Prerequisite: 15-451 Min. grade B

15-458 Discrete Differential Geometry

Spring: 12 units

This course focuses on three-dimensional geometry processing, while simultaneously providing a first course in traditional differential geometry. Our main goal is to show how fundamental geometric concepts (like curvature) can be understood from complementary computational and mathematical points of view. This dual perspective enriches understanding on both sides, and leads to the development of practical algorithms for working with real-world geometric data. Along the way we will revisit important ideas from calculus and linear algebra, putting a strong emphasis on intuitive, visual understanding that complements the more traditional formal, algebraic treatment. The course provides essential mathematical background as well as a large array of real-world examples and applications. It also provides a short survey of recent developments in digital geometry processing and discrete differential geometry. Topics include: curves and surfaces, curvature, connections and parallel transport, exterior algebra, exterior calculus, Stokes' theorem, simplicial homology, de Rham cohomology, Helmholtz-Hodge decomposition, conformal mapping, finite element methods, and numerical linear algebra. Applications include: approximation of curvature, curve and surface smoothing, surface parameterization, vector field design, and computation of geodesic distance. Prerequisites: (02-201 Min. grade C or 15-110 Min. grade C or 15-122 Min. grade C or 15-112 Min. grade C) and (21-240 Min. grade C or 21-254 Min. grade C or 21-242 Min. grade C or 21-241 Min. grade C or 21-341 Min. grade C) and (21-269 Min. grade C or 21-259 Min. grade C or 21-268 Min. grade C or 21-256 Min. grade C or 21-254 Min. grade C)

Course Website: <http://geometry.cs.cmu.edu/ddg> (<http://geometry.cs.cmu.edu/ddg/>)

15-459 Undergraduate Quantum Computation

Intermittent: 9 units

This undergraduate course will be an introduction to quantum computation and quantum information theory, from the perspective of theoretical computer science. Topics include: Qubit operations, multi-qubit systems, partial measurements, entanglement, quantum teleportation and quantum money, quantum circuit model, Deutsch-Jozsa and Simon's algorithm, number theory and Shor's Algorithm, Grover's Algorithm, quantum complexity theory, limitations and current practical developments. Prerequisites: (15-210 Min. grade C or 15-251 Min. grade C) and (36-225 or 15-259 or 36-218 or 33-341 or 21-325) and (21-241 Min. grade C or 21-242 or 33-341)

15-462 Computer Graphics

Fall and Spring: 12 units

This course provides a comprehensive introduction to computer graphics modeling, animation, and rendering. Topics covered include basic image processing, geometric transformations, geometric modeling of curves and surfaces, animation, 3-D viewing, visibility algorithms, shading, and ray tracing.

Prerequisites: (15-213 Min. grade C and 21-240 Min. grade C and 21-259 Min. grade C) or (15-213 Min. grade C and 21-241 Min. grade C and 21-259 Min. grade C) or (18-202 Min. grade C and 18-213 Min. grade C)

15-463 Computational Photography

Fall: 12 units

Computational photography is the convergence of computer graphics, computer vision and imaging. Its role is to overcome the limitations of the traditional camera, by combining imaging and computation to enable new and enhanced ways of capturing, representing, and interacting with the physical world. This advanced undergraduate course provides a comprehensive overview of the state of the art in computational photography. At the start of the course, we will study modern image processing pipelines, including those encountered on mobile phone and DSLR cameras, and advanced image and video editing algorithms. Then we will proceed to learn about the physical and computational aspects of tasks such as 3D scanning, coded photography, lightfield imaging, time-of-flight imaging, VR/AR displays, and computational light transport. Near the end of the course, we will discuss active research topics, such as creating cameras that capture video at the speed of light, cameras that look around walls, or cameras that can see through tissue. The course has a strong hands-on component, in the form of seven homework assignments and a final project. In the homework assignments, students will have the opportunity to implement many of the techniques covered in the class, by both acquiring their own images of indoor and outdoor scenes and developing the computational tools needed to extract information from them. For their final projects, students will have the choice to use modern sensors provided by the instructors (lightfield cameras, time-of-flight cameras, depth sensors, structured light systems, etc.). This course requires familiarity with linear algebra, calculus, programming, and doing computations with images. The course does not require prior experience with photography or imaging. Prerequisites: 15-462 Min. grade C or 18-793 Min. grade C or 16-385 Min. grade C or 16-720 Min. grade C

Course Website: <http://graphics.cs.cmu.edu/courses/15-463/>

15-464 Technical Animation

Spring: 12 units

This course introduces techniques for computer animation such as keyframing, procedural methods, motion capture, and simulation. The course also includes a brief overview of story-boarding, scene composition, lighting and sound track generation. The second half of the course will explore current research topics in computer animation such as dynamic simulation of flexible and rigid objects, automatically generated control systems, and evolution of behaviors. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

Prerequisite: 15-462 Min. grade C

15-465 Animation Art and Technology

Spring: 12 units

Animation, Art, and Technology is an interdisciplinary, Art and Computer Science, cross-listed course. Faculty and teaching assistants from computer science and art teach the class as a team. It is a project-based course in which interdisciplinary teams of students can produce animations across platforms from single channel to augmented reality. Most of the animations have a substantive technical component and the students are challenged to consider innovation with content to be equal with the technical. The class includes basic tutorials for work in Maya and Unity leading toward more advanced applications and extensions of the software such as motion capture and algorithms for animating cloth, hair, particles, and immersive technologies.

Prerequisites: 15-213 Min. grade C or 18-213 Min. grade C

15-466 Computer Game Programming

Fall: 12 units

The goal of this course is to acquaint students with the code required to turn ideas into games. This includes both runtime systems and #8212; e.g., AI, sound, physics, rendering, and networking and #8212; and the asset pipelines and creative tools that make it possible to author content that uses these systems. In the first part of the course, students will implement small games that focus on specific runtime systems, along with appropriate asset editors or exporters. In the second part, students will work in groups to build a larger, polished, open-ended game project. Students who have completed the course will have the skills required to extend and #8212; or build from scratch and #8212; a modern computer game. Students wishing to take this class should be familiar with the C++ language and have a basic understanding of the OpenGL API. If you meet these requirements but have not taken 15-462 (the formal prerequisite), please contact the instructor.

Prerequisite: 15-462

15-468 Physics-Based Rendering

Spring: 12 units

This course is an introduction to physics-based rendering at the advanced undergraduate and introductory graduate level. During the course, we will cover fundamentals of light transport, including topics such as the rendering and radiative transfer equation, light transport operators, path integral formulations, and approximations such as diffusion and single scattering. Additionally, we will discuss state-of-the-art models for illumination, surface and volumetric scattering, and sensors. Finally, we will use these theoretical foundations to develop Monte Carlo algorithms and sampling techniques for efficiently simulating physically-accurate images. Towards the end of the course, we will look at advanced topics such as rendering wave optics, neural rendering, and differentiable rendering. The course has a strong programming component, during which students will develop their own working implementation of a physics-based renderer, including support for a variety of rendering algorithms, materials, illumination sources, and sensors. The project also includes a final project, during which students will select and implement some advanced rendering technique, and use their implementation to produce an image that is both technically and artistically compelling. The course will conclude with a rendering competition, where students submit their rendered images to win prizes. Cross-listing: This is both an advanced undergraduate and introductory graduate course, and it is cross-listed as 15-468 (for undergraduate students), 15-668 (for Master's students), and 15-868 (for PhD students). Please make sure to register for the section of the class that matches your current enrollment status. Prerequisites: 16-385 or 16-720 or 15-462

Course Website: <http://graphics.cs.cmu.edu/courses/15-468/>**15-469 Special Topic: Visual Computing Systems**

Intermittent: 12 units

Visual computing tasks such as computational imaging, image/video understanding, and real-time graphics are key responsibilities of modern computer systems ranging from sensor-rich smart phones to large datacenters. These workloads demand exceptional system efficiency and this course examines the key ideas, techniques, and challenges associated with the design of parallel, heterogeneous systems that accelerate visual computing applications. This course is intended for graduate and advanced undergraduate-level students interested in architecting efficient graphics, image processing, and computer vision platforms. Prerequisites: 15-418 or 16-385 or 15-462

15-482 Autonomous Agents

Fall: 12 units

Autonomous agents use perception, cognition, actuation, and learning to reliably achieve desired goals, where the agents can be smart homes, mobile robots, intelligent factories, self-driving cars, etc. The goal of this course is to introduce students to techniques needed for developing complete, integrated AI-based autonomous agents. Topics include architectures for intelligent agents; autonomous behaviors, perception, and execution; reasoning under uncertainty; optimization; execution monitoring; machine learning; scheduling; and explanation. A focus of the course will be on the integration and testing of autonomous systems to achieve reliable and robust behavior in the face of sensor noise and uncertainty. The course is project-oriented where small teams of students will design, implement, and evaluate agents that can grow plants autonomously, without human intervention.

Prerequisites: 10-601 or 10-315 or 10-301 or 15-281

Course Website: <http://www.cs.cmu.edu/~15482> (<http://www.cs.cmu.edu/~15482/>)**15-483 Truth, Justice, and Algorithms**

Intermittent: 9 units

Truth, Justice, and Algorithms is an interdisciplinary course that covers selected theoretical topics at the interface of computer science and economics, focusing on the algorithmic side of incentives and fairness. The course's topics include: computational social choice, e.g., voting rules as maximum likelihood estimators, the axiomatic approach to ranking systems and crowdsourcing, manipulation of elections and ways to circumvent it; cooperative games, focusing on solution concepts such as the core and the Shapley value, and their computation; fair division algorithms for allocating divisible and indivisible goods, and approximate notions of fairness; online matching algorithms (competitive analysis, not dating) and kidney exchange; noncooperative games, including Nash equilibrium and correlated equilibrium, their computation, connections to learning theory, Stackelberg security games, and the price of anarchy in congestion and routing games; and topics in social networks such as the diffusion of technologies and influence maximization. NOTE: This course is cross-listed with 15-896. Undergraduates may enroll into 15-896 but be aware of work load difference. The two courses are identical in terms of lectures, content, and homework assignments. The only difference is in the final project requirement. In 483, students will prepare a summary of several papers and #8212; this will require 10-20 hours of work. In 896, students will carry out a research project with the goal of obtaining novel results, and present their results in class and #8212; a good project will require 50-60 hours of work. Also note that 483 is 9 units, and 896 is 12 units.

Prerequisite: 15-451 Min. grade C

Course Website: <http://www.cs.cmu.edu/~arielpro/15896s16/>**15-487 Introduction to Computer Security**

Fall: 12 units

This course will introduce students to the fundamentals of computer security and applied cryptography. Topics include software security, networking and wireless security, and applied cryptography. Students will also learn the fundamental methodology for how to design and analyze security critical systems.

Prerequisite: 15-213

15-491 Special Topic: CMRoboBits: AI and Robots for Daily-Life Problems

Fall: 12 units

This course will be a project-based course in which we will look at AI and robotics artifacts and techniques to automate solutions to real-world problems, in particular related to life in cities. The course will start by collecting and brainstorming about real problems biased to ones that involve the physical space in addition to the cyber information space, such as traffic rush hour, noise in cities, 3D building inspection, service and data gathering. We will then formalize the chosen problems and analyze existing real data. The course will proceed by possibly enabling the students to prototype their projects beyond simulation, and using the CORAL lab robots, e.g., the CoBot or NAO robots or drones. The course work will be a single large project, performed by groups of up to 3 students. The projects will be divided in three phases, due at the end of February, March, and the end of the course. Students are expected to have programming experience in C++ or python.

Prerequisite: 15-122 Min. grade C

15-492 Special Topic: Speech Processing

Fall: 12 units

Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, build their own synthetic voice and build a complete telephone spoken dialog system. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.

Prerequisite: 15-122 Min. grade C

Course Website: <http://www.speech.cs.cmu.edu/15-492/>

15-494 Cognitive Robotics: The Future of Robot Toys

Spring: 12 units

This course will explore the future of robot toys by analyzing and programming Anki Cozmo, a new robot with built-in artificial intelligence algorithms. Como is distinguished from earlier consumer robots by its reliance on vision as the primary sensing mode and its sophisticated use of A.I. Its capabilities include face and object recognition, map building, path planning, and object pushing and stacking. Although marketed as a pre-programmed children's toy, Cozmo's open source Python SDK allows anyone to develop new software for it, which means it can also be used for robotics education and research. The course will cover robot software architecture, human-robot interaction, perception, and planning algorithms for navigation and manipulation. Prior robotics experience is not required, just strong programming skills.

Prerequisite: 15-122 Min. grade C

15-495 Topics of Algorithmic Problem Solving

Intermittent: 12 units

This course aims to give implementation motivated perspectives on some algorithmic ideas that fall outside of the scopes of most courses. It is intended for graduate students, as well as undergraduate students who have high grades in 15-210, 15-251, 15-259 (and preferably 15-451). Evaluation will consist of about 30 auto-graded coding tasks, plus either participation in the East Central NA ICPC Regional Contest, or presentations of problem-solving reports from the Chinese IOI Team Selection Camp. The first half of the course will discuss floating point precision, numerical approximation schemes, heuristic search, usage of optimization packages, and vectorization. The second half will provide high-level surveys of 2-D range update and amp; query data structures, proactive propagation, palindromic automata, automated recurrence finding, and maximum adjacency search.

Prerequisites: (15-259 Min. grade C or 21-235 Min. grade C) and 15-210 Min. grade C and 15-251 Min. grade C

15-503 This course is now 15-356 / 856 Introduction to Cryptography

Spring: 9 units

This course is aimed as an introduction to theoretical cryptography for graduate and advanced undergraduate students. We will cover formal definitions of security, as well as constructions of some of the most useful and popular primitives in cryptography: pseudorandom generators, encryption, signatures, zero-knowledge, multi-party computation, etc. In addition, we will cover the necessary number-theoretic background.

Prerequisites: 15-251 Min. grade C and 15-210 Min. grade C

Course Website: <http://www.cs.cmu.edu/~goyal/15503.html>**15-539 Computer Science Pedagogy**

Spring: 9 units

The objective of this course is to build skills in the area of collaborative product design in an educational context. The first part of the course will focus on how to communicate with and engage an audience in an ever-growing virtual environment, using computer science education as the medium. The goal will be to learn how to present information in a creative yet intrinsically pedagogical way. Throughout the course, students will work both independently and in groups to create content for high school students using CMU CS Academy's computer programming curriculum. Contact ecawley@andrew.cmu.edu if you are interested in taking this class as it is special permission only.

15-591 Independent Study in Computer Science

Fall and Spring

The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-592 Independent Study in Computer Science

Fall and Spring

The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-593 Independent Study in Computer Science

Fall and Spring

The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-594 Independent Study in Computer Science

Fall and Spring

The School of Computer Science offers Independent Study courses, which allow motivated students to work on projects under the supervision of a faculty advisor while receiving academic credit. Independent studies are usually one semester in duration and require prior approval from the faculty member and the School of Computer Science.

15-599 SCS Honors Undergraduate Research Thesis

Fall and Spring

Available only to students registered in the CS Senior Research Thesis Program.

15-627 Monte Carlo Methods and Applications

Fall: 9 units

Course Description: The Monte Carlo method uses random sampling to solve computational problems that would otherwise be intractable, and enables computers to model complex systems in nature that are otherwise too difficult to simulate. This course provides a first introduction to Monte Carlo methods from complementary theoretical and applied points of view, and will include implementation of practical algorithms. Topics include random number generation, sampling, Markov chains, Monte Carlo integration, stochastic processes, and applications in computational science. Students need a basic background in probability, multivariable calculus, and some coding experience in any language.

Course Website: <http://www.cs.cmu.edu/~kmcrae/random/>**15-635 Foundations of Blockchains**

Fall: 12 units

In this course, students will learn the mathematical foundations of blockchains, including how to construct distributed consensus protocols and prove them secure, cryptography for blockchains, and mechanism design for blockchains. This course will take a mathematically rigorous approach. Students are expected to have mathematical maturity and be able to write formal mathematical proofs. Students may also be expected to implement some consensus or cryptographic algorithms. This course is crosslisted with 15-435. Graduate students should take 15-635. Undergraduates should take 15-435.

Prerequisites: 15-330 or 15-210 Min. grade C or 15-251 Min. grade C

15-668 Physics-Based Rendering

Spring: 12 units

This course is an introduction to physics-based rendering at the advanced undergraduate and introductory graduate level. During the course, we will cover fundamentals of light transport, including topics such as the rendering and radiative transfer equation, light transport operators, path integral formulations, and approximations such as diffusion and single scattering. Additionally, we will discuss state-of-the-art models for illumination, surface and volumetric scattering, and sensors. Finally, we will use these theoretical foundations to develop Monte Carlo algorithms and sampling techniques for efficiently simulating physically-accurate images. Towards the end of the course, we will look at advanced topics such as rendering wave optics, neural rendering, and differentiable rendering.

Prerequisites: 16-720 or 16-385 or 15-462

Course Website: <http://graphics.cs.cmu.edu/courses/15-468/>**15-669 Special Topics: Visual Computing Systems**

Intermittent: 12 units

Visual computing tasks such as computational imaging, image/video understanding, and real-time graphics are key responsibilities of modern computer systems ranging from sensor-rich smart phones to large datacenters. These workloads demand exceptional system efficiency and this course examines the key ideas, techniques, and challenges associated with the design of parallel, heterogeneous systems that accelerate visual computing applications. This course is intended for graduate and advanced undergraduate-level students interested in architecting efficient graphics, image processing, and computer vision platforms.

Prerequisites: 15-418 or 16-385 or 15-462

15-705 Engineering Distributed Systems

Spring: 12 units

This course is for students with strong design and implementation skills who are likely to pursue careers as software architects and lead engineers. It may be taken by well-prepared undergraduates with excellent design and implementation skills in low-level systems programming. The course assumes a high level of proficiency in all aspects of operating system design and implementation. This course will help students prepare for leadership roles in creating and evolving the complex, large-scale computer systems that society will increasingly depend on in the future. The course will teach the organizing principles of such systems, identifying a core set of versatile techniques that are applicable across many system layers. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered computer systems that withstand the test of time, growth in scale, and stresses of live use. Topics covered include: caching, prefetching, damage containment, scale reduction, hints, replication, hash-based techniques, and fragmentation reduction. A substantial project component is an integral part of the course. A high level of proficiency in systems programming is expected. Please refer to course website for the most recent schedule updates.

Course Website: <http://www.cs.cmu.edu/~csd-grad/courseschedules14.html>**15-719 Advanced Cloud Computing**

Spring: 12 units

Computing in the cloud has emerged as a leading paradigm for cost-effective, scalable, well-managed computing. Users pay for services provided in a broadly shared, power efficient datacenter, enabling dynamic computing needs to be met without paying for more than is needed. Actual machines may be virtualized into machine-like services, or more abstract programming platforms, or application-specific services, with the cloud computing infrastructure managing sharing, scheduling, reliability, availability, elasticity, privacy, provisioning and geographic replication. This course will survey the aspects of cloud computing by reading about 30 papers and articles, executing cloud computing tasks on a state of the art cloud computing service, and implementing a change or feature in a state of the art cloud computing framework. There will be no final exam, but there will be two in class exams. Grades will be about 50 project work and about 50 examination results. Prerequisites: 15-213 Min. grade B or 18-213 Min. grade B or 15-513 Min. grade B

Course Website: <http://www.cs.cmu.edu/~15719/>**15-749 Engineering Distributed Systems**

Fall: 12 units

Computing has changed beyond recognition in half a century, from the room-filling mainframes of the 1960s to today's smartphones and wearable devices. Networks have also changed dramatically: from the 300-baud dialup modems of the early networking era to gigabit LANs, Wi-Fi and 4G today. Who knows what changes are in store for us over the next half century? Astonishingly, in spite of this tremendous change in hardware technology over time, a small core set of techniques for building distributed systems has emerged and remained surprisingly stable and applicable across many system layers. Many flavors of these techniques exist, and they continuously evolve over time to reflect changing trade-offs in the design space. What are these core techniques, and how can we leverage them in creating distributed systems today and in the future? That is the central question addressed by this course. Students will acquire the knowledge base, intellectual tools, hands-on skills and modes of thought needed to build well-engineered distributed systems that withstand the test of time, growth in scale, and stresses of live use. Strong design and implementation skills are expected of all students. The course assumes a high level of proficiency in all aspects of operating system design and implementation. A substantial project component is an integral part of the course. Please refer to <http://www.cs.cmu.edu/~csd-grad/courseschedules14.html> this link for the most recent schedule updates.

Course Website: <http://www.cs.cmu.edu/~15-749/>**15-751 A Theorist's Toolkit**

Intermittent: 12 units

Course description This course will take a random walk through various mathematical topics that come in handy for theoretical computer science. It is intended mainly for students earlier in their graduate studies (or very strong undergraduates) who want to do theory research. The idea for the course comes from other courses by Arora (2002, 2007), Håstad (2004/05), Kelner (2007, 2009), and Tulsiani (2013). Prerequisites Students should have a solid undergraduate background in math (e.g., elementary combinatorics, graph theory, discrete probability, basic algebra/calculus) and theoretical computer science (running time analysis, big-O/Omega/Theta, P and NP, basic fundamental algorithms). Mathematical maturity is a must. Grading scheme The course grades will be determined as follows: 68%: Homework 12%: Written project 8%: Project peer review 6%: Seminar attendance 3%: Class participation Resources Scribe notes from an earlier version of the course. A textbook you might find helpful: The Nature of Computation by Cris Moore and Stephan Mertens. <https://www.cs.cmu.edu/~csd-grad/courseschedules22.html>

Course Website: <http://www.cs.cmu.edu/~odonnell/toolkit22/>**15-769 Special Topics in Graphics: Physically-based Animation of Solids and Fluids**

Fall: 12 units

This seminar-based course delves into the heart of physically-based animations of solids and fluids, a key component in fields ranging from visual effects and VR to digital fashion. Central to this is solving partial differential equations (PDEs) using numerical methods, with applications extending to computational mechanics, robotic training, and 3D content creation. Combining lectures with student presentations, we will explore the simulation of various physical entities, such as rigid bodies, deformable bodies, shells, rods, liquids, and smoke, all the way from the discretization of the governing PDEs to the efficient implementation and evaluation of the numerical solvers.

Course Website: <http://www.cs.cmu.edu/~15769-f23/>**15-883 Computational Models of Neural Systems**

Intermittent: 12 units

This course is an in-depth study of information processing in real neural systems from a computer science perspective. We will examine several brain areas, such as the hippocampus and cerebellum, where processing is sufficiently well understood that it can be discussed in terms of specific representations and algorithms. We will focus primarily on computer models of these systems, after establishing the necessary anatomical, physiological, and psychophysical context. There will be some neuroscience tutorial lectures for those with no prior background in this area.

Course Website: <http://www.cs.cmu.edu/afs/cs/academic/class/15883-f19/>

Human-Computer Interaction Courses

05-090 Human-Computer Interaction Practicum

All Semesters: 3 units

This course is for HCI students who wish to have an internship experience as part of their curriculum. Students are required to write a one-page summary statement prior to registration that explains how their internship connects with their HCI curriculum, specifically on how it uses material they have learned as well as prepares them for future courses. Near the end of the internship, students will be required to submit a reflection paper that describes the work they did in more detail, including lessons learned about the work experience and how they utilized their HCI education to work effectively. International students should consult with the Office of International Education for appropriate paperwork and additional requirements before registration. Units earned count toward the total required units necessary for degree completion; students should speak with an academic advisor for details. This course may be taken at most 3 times for a total of 9 units maximum. Students normally register for this course for use during the summer semester.

05-120 Introduction to Human-Computer Interaction

Spring: 5 units

This course is only for freshman SCS students that are interested in learning more about HCI.

05-200 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-291 Learning Media Design

Fall: 12 units

[IDeATe collaborative course] Learning is a complex human phenomenon with cognitive, social and personal dimensions that need to be accounted for in the design of technology enhanced learning experiences. In this studio course students will apply learning science concepts to critique existing forms of learning media, establish a set of design precedents to guide project work and produce a series of design concepts that support learning interactions in a real-world context. Collaborating in small interdisciplinary teams, students will partner with a local informal learning organization (e.g. museum, after school program provider, maker space) to conduct learning design research studies, synthesize findings, establish learning goals and iteratively prototype and assess design concepts. As final deliverables, students will present their design research findings, design concepts, and prototypes to stakeholders, and draft a media-rich proposal for their learning media concept to pitch to a local funder. Please note that there may be usage/materials fees associated with this course. Please note that there may be usage/materials fees associated with this course.

05-292 IDeATe: Learning in Museums

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences through a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts that improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions. This course will culminate in a media-rich presentation of design concepts and a prototype to a stakeholder audience, and include an evaluation plan describing how learning outcomes for the project would be assessed.

05-300 HCI Undergraduate Pro Seminar

All Semesters: 2 units

HCI is a broad field that brings together approaches from design, computer science, and psychology. This course provides an introduction to the field of HCI and to the HCI community at CMU. Guest speakers from around campus will provide a general introduction to these approaches and how they are pursued at CMU, and will describe research opportunities that are available to undergraduates. The course will also discuss career options in both industry and academia for students of HCI, and will include presentations from HCI alumni and sessions on preparing resumes, creating portfolios, and interviewing for jobs. The course is designed for current or potential HCI majors and minors but is open to anyone with an interest in applying for the HCI major/minor.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-315 Persuasive Design

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-317 Design of Artificial Intelligence Products

Intermittent: 12 units

This course teaches students how to design new products and services that leverage the capabilities of AI and machine learning to improve the quality of peoples lives. Students will learn to follow a matchmaking design, user-centered design, and service design process. Students will learn to ideate; reframing problematic situations by envisioning many possible products and services. Students will learn to iteratively refine and assess their ideas with real users/customers. Class projects will focus on the challenges of deploying systems that generate errors and the challenges of situating intelligent systems such that they harmonize the best qualities of human and machine intelligence.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-318 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <http://www.hcii.cmu.edu/academics/courses> (<http://www.hcii.cmu.edu/academics/courses/>)

05-319 Data Visualization

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>

05-320 Social Web

Intermittent: 12 units

With the growth of online environments like MySpace, Second Life, World of Warcraft, Wikipedia, blogs, online support groups, and open source development communities, the web is no longer just about information. This course, jointly taught by a computer scientist and a behavioral scientist, will examine a sampling of the social, technical and business challenges social web sites must solve to be successful, teach students how to use high-level tools to analyze, design or build online communities, and help them understand the social impact of spending at least part of their lives online. This class is open to advanced undergraduates and graduate students with either technical or non-technical backgrounds. Course work will include lectures and class discussion, homework, class presentations, and a group research or design project.

05-321 Transformational Game Design Studio

Fall: 12 units

TBA

05-333 Gadgets, Sensors and Activity Recognition in HCI

Fall: 12 units

Recent advances in HCI have been driven by new capabilities to deliver inexpensive devices to users, to display information in mobile and other contexts, to sense the user and their environment, and use these sensors to create models of a user's context and actions. This course will consider both concepts surrounding these new technological opportunities through discussion of current literature - and practical considerations the skills needed to actually build devices. About 1/3 of this class will review current advances in this area. The remainder will be devoted to development of individual skills so that students leaving the class will have an ability to actually build small devices for human interaction (in short: "HCI gadgets"). In particular, the course will concentrate on the basics of building simple microcontroller-based devices and will also provide very basic coverage of the machine learning techniques needed for simple sensor-driven statistical models. The course is designed to be accessible to students with a wide range of backgrounds including both technically-oriented and non-technical students (especially Designers) interested in HCI. The class will be project oriented with 4-5 electronic prototype building projects during the semester. At least two of these projects will be self-defined in nature and can be adapted to the existing skills and interests of each student. There are no formal prerequisites for this class. However, the class will involve programming and debugging of micro-controllers. Some coverage of the language used to do this will be provided, and if required by your background, the programming component of the projects can be made comparatively small (but, in that case some other aspect of the projects will need to be expanded). However, you should not take this course if you have no programming background. This course assumes no background in electronics.

Course Website: <http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci> (<http://www.hcii.cmu.edu/courses/applied-gadgets-sensors-and-activity-recognition-hci/>)

05-341 Organizational Communication

All Semesters: 9 units

Most of management is communication. You communicate to get information that will be the basis of decisions, coordinate activity, to provide a vision for the people who work for and with you, to and to sell yourself and your work. The goal of this course is to identify communication challenges within work groups and organizations and ways to overcome them. To do this requires that we know how communication normally works, what parts are difficult, and how to fix it when it goes wrong. The focus of this course is on providing you with a broad understanding of the way communication operates within dyads, work groups, and organizations. The intent is to give you theoretical and empirical underpinnings for the communication you will undoubtedly participate in when you move to a work environment, and strategies for improving communication within your groups. Because technology is changing communication patterns and outcomes both in organizations and more broadly in society, the course examines these technological changes. Readings come primarily from the empirical research literature.

Course Website: <http://www.hcii.cmu.edu/courses/organizational-communication> (<http://www.hcii.cmu.edu/courses/organizational-communication/>)

05-360 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-361 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-380 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with permission of the instructor. Prerequisites: 15-112 and (15-122 or 15-121 or 15-150 or 15-210) and (05-410 or 05-391) and (05-452 or 05-650 or 05-651 or 05-470 or 05-317)

05-391 Designing Human Centered Software

All Semesters: 12 units

"Why are things so hard to use these days? Why doesn't this thing I just bought work? Why is this web site so hard to use? These are frustrations that we have all faced from systems not designed with people in mind. The question this course will focus on is: how can we design human-centered systems that people find useful and usable? This course is a broad introduction to designing, prototyping, and evaluating user interfaces. If you take only one course in Human-Computer Interaction, this is the course for you. We will cover theory as well as practical application of ideas from Human-Computer Interaction. Coursework includes lectures, class discussion, homework, class presentations, and group projects. This class is open to all undergrads and grad students, with either technical or non-technical majors. However, there is a programming prerequisite. " Prerequisites: 15-110 or 15-104 or 15-122 or 15-112

Course Website: <http://www.hcii.cmu.edu/courses/designing-human-centered-software> (<http://www.hcii.cmu.edu/courses/designing-human-centered-software/>)

05-392 Interaction Design Overview

Fall: 9 units

This studio course offers a broad overview of communication and interaction design. Students will learn design methodologies such as brainstorming, sketching, storyboarding, wire framing, and prototyping. Students learn to take a human-centered design approach to their work. Assignments include short in-class exercises as well as individual and team-based projects. Students take part in studio critiques, engaging in critical discussions about the strengths and weaknesses of their own work and the work of others. No coding is required.

05-395 Applications of Cognitive Science

Spring: 9 units

The goal of this course is to examine cases where basic research on cognitive science, including cognitive neuroscience, has made its way into application, in order to understand how science gets applied more generally. The course focuses on applications that are sufficiently advanced as to have made an impact outside of the research field per se; for example, as a product, a change in practice, or a legal statute. Examples are virtual reality (in vision, hearing, and touch), cognitive tutors, phonologically based reading programs, latent semantic analysis applications to writing assessment, and measures of consumers' implicit attitudes. The course will use a case-study approach that considers a set of applications in detail, while building a general understanding of what it means to move research into the applied setting. The questions to be considered include: What makes a body of theoretically based research applicable? What is the pathway from laboratory to practice? What are the barriers - economic, legal, entrenched belief or practice? The format will emphasize analysis and discussion by students. They should bring to the course an interest in application; extensive prior experience in cognitive science is not necessary. The course will include tutorials on basic topics in cognitive science such as perception, memory, and spatial cognition. These should provide sufficient grounding to discuss the applications.

Course Website: <http://www.hcii.cmu.edu/courses/applications-cognitive-science> (<http://www.hcii.cmu.edu/courses/applications-cognitive-science/>)

05-410 User-Centered Research and Evaluation

Fall: 12 units

This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology and teaches the basic skills of generative and evaluative research methods. This is a companion course to courses in visual design (51-422) and software implementation (05-430, 05-431). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI second major and year in school e.g. seniors, juniors, etc In the Fall, this course is NOT open to students outside the HCI major. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major.

05-413 Human Factors

Fall: 9 units

This course uses theory and research from human factors, cognitive science, and social science to understand and design the interactions of humans with the built world, tools, and technology. The course emphasizes current work in applied domains such as automotive design, house construction, medical human factors, and design of information devices. The course also will emphasize not only individual human factors (e.g., visual response, anthropometry) but also the organizational arrangements that can amplify or correct human factors problems. Through reading, discussion, and projects, you will learn about human perceptual, cognitive, and physical processes that affect how people interact with, and use, technology and tools. You will learn why we have so many automobile accidents, voting irregularities, and injuries from prescription medication. You will learn some tried and true solutions for human factors problems, and some of the many problems in human factors that remain. You will also have gained experience in research in this field.

Course Website: <http://www.hcii.cs.cmu.edu>

05-417 Computer-mediated Communication

Spring: 6 units

This course examines fundamental aspects of interpersonal communication and considers how different types of computer-mediated communications (CMC) technologies affect communication processes. Among the topics we will consider are: conversational structure and CMC, tools to support nonverbal and paralinguistic aspects of communication such as gesture and eye gaze, and social and cultural dimensions of CMC. Students will be expected to post to weekly discussion lists, to write a paper on a specific aspect of CMC, and to present a talk on their final project to the class. The course should be appropriate for graduate students in all areas and for advanced undergraduates.

05-418 Design Educational Games

Spring: 12 units

The potential of digital games to improve education is enormous. However, it is a significant challenge to create a game that is both fun and educational. In this course, students will learn to meet this challenge by combining processes and principles from game design and instructional design. Students will also learn to evaluate their games for fun, learning, and the integration of the two. They will be guided by the EDGE framework for the analysis and design educational games. The course will involve a significant hands-on portion, in which students learn a design process to create educational games digital or non-digital. They will also read about existing educational games and discuss game design, instructional design, learning and transfer, and the educational effectiveness of digital games. They will analyze an educational game and present their analysis to the class.

Course Website: <https://www.hcii.cmu.edu/course/design-of-educational-games> (<https://www.hcii.cmu.edu/course/design-of-educational-games/>)

05-430 Programming Usable Interfaces

Spring: 15 units

This course is combines lecture, and an intensive programming lab and design studio. It is for those who want to express their interactive ideas in working prototypes. It will cover the importance of human-computer interaction/interface design, iterative design, input/output techniques, how to design and evaluate interfaces, and research topics that will impact user interfaces in the future. In lab, you will learn how to design and program effective graphical user interfaces, and how to perform user tests. We will cover a number of prototyping tools and require prototypes to be constructed in each, ranging from animated mock-ups to fully functional programs. Assignments will require implementing UIs, testing that interface with users, and then modifying the interface based on findings. Some class sessions will feature design reviews of student work. This course is for HCII Masters students and HCI dual majors with a minimal programming background. Students will often not be professional programmers, but will need to interact with programmers. RECITATION SELECTION: Students taking this course can sign up for either Prototyping Lab recitation. PREREQUISITES: Proficiency in a programming language, program structure, algorithm analysis, and data abstraction. Normally met through an introductory programming course using C, C++, Pascal or Java, such as 15100, 15112, 15127 or equivalent. Students entering this course should be able to independently write a 300-line program in 48 hours. This course is NOT open to students outside of the BHCI program. Prerequisites: 15-127 or 15-112 or 15-110 or 15-104 or 15-100

05-431 Software Structures for User Interfaces

Fall: 12 units

This course considers the basic and detailed concepts for building software to implement user interfaces (UIs). It considers factors of input, output, application interface, and related infrastructure as well as the typical patterns used to implement them. It considers how these aspects are organized and managed within a well-structured object oriented system. We will cover a variety of "front-end" programming contexts, including conventional graphical user interface (GUI) programming for mobile apps (phones, watches), web apps, and regular desktop applications, across a variety of frameworks. We will also cover programming for data-driven and conversational (AI) user interfaces. We will briefly touch on front-end programming for visualizations, games, 3D, and virtual and artificial reality (VR and AR), along with interactive UI tools such as prototypers and resource editors. The homeworks and project in this course will involve extensive object-oriented programming, likely in both Java and JavaScript, so this course is only appropriate for students with a strong programming background. Note that this is not an HCI methods course and #8212; we do not cover user-centered design or evaluation methods. This course is designed for students in the SCS HCI undergrad Major, but it also available to any undergrad or graduate student with an interest in the topic and solid prior programming experience who wish to understand the structures needed for professional development of interactive systems. Note that all students who register for this class will initially be placed on a waitlist. Priority for getting into the class are students in the HCII programs (more senior students first), and then others. The graduate (05-631) and undergraduate (05-431) numbers are for the same course with the same work.

Prerequisites: 17-514 or 17-437 or 17-214 or 14-513 or 15-513 or 18-213 or 15-213 or 15-214

05-432 Personalized Online Learning

Fall: 12 units

Online learning has become widespread (e.g., MOOCs, online and blended courses, and Khan Academy) and many claim it will revolutionize higher education and K-12. How can we make sure online learning is maximally effective? Learners differ along many dimensions and they change over time. Therefore, advanced learning technologies must adapt to learners to provide individualized learning experiences. This course covers a number of proven personalization techniques used in advanced learning technologies. One of the techniques is the use of cognitive modeling to personalize practice of complex cognitive skills in intelligent tutoring systems. This approach, developed at CMU, may well be the most significant application of cognitive science in education and is commercially successful. We will also survey newer techniques, such as personalizing based on student meta-cognition, affect, and motivation. Finally, we will look at personalization approaches that are widely believed to be effective but have not proven to be so. The course involves readings and discussion of different ways of personalizing instruction, with an emphasis on cognitive modeling approaches. Students will learn to use the Cognitive Tutor Authoring Tools (CTAT) to implement tutor prototypes that rely on computer-executable models of human problem solving to personalize instruction. The course is meant for graduate or advanced undergraduate students in Human-Computer Interaction, Psychology, Computer Science, Design, or related fields, who are interested in educational applications. Students should either have some programming skills or experience in the cognitive psychology of human problem solving, or experience with instructional design.

Course Website: <http://www.hcii.cmu.edu/courses/personalized-online-learning> (<http://www.hcii.cmu.edu/courses/personalized-online-learning/>)

05-433 Programming Usable Interfaces OR Software Structures for Usable Interfaces

Fall: 6 units

Section A: Programming Usable Interfaces Section B: Software Structures for Usable Interfaces This is a lecture-only course (see 05-430/05-630 or 05-431/631 for the lecture + lab version of these courses) that is intended for those who want to learn how to design and evaluate user interfaces. We will cover the importance of human-computer interaction and interface design, the iterative design cycle used in HCI, an overview of input and output techniques, how to design and evaluate interaction techniques, and end with a discussion of hot topics in research that will impact user interfaces in the coming years. This course is only intended for HCII Masters students or HCI undergraduate majors who have already taken an associated User Interface lab, or non-MHCI/BHCI students interested in the design of user interfaces. WAITLIST LOGISTICS: Note that ALL students who register for this class will initially be placed on a waitlist. Your position on the waitlist is not an indication of whether you will be accepted into the class. Contacting the instructor will not move you off the waitlist. Priority for getting off the waitlist are MHCI students, BHCI students (more senior students first), and then others.

05-434 Machine Learning in Practice

Fall and Spring: 12 units

Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization. 05-834 is the HCII graduate section. If you are an LTI student, please sign up for the LTI graduate course number (11-663) ONLY to count properly towards your degree requirements. 05-434 is the HCII undergraduate section. If you are an LTI student, please sign up for the LTI undergraduate course number (11-344) ONLY to count properly towards your degree requirements.

Course Website: <http://www.hcii.cmu.edu/courses/applied-machine-learning> (<http://www.hcii.cmu.edu/courses/applied-machine-learning/>)

05-435 Applied Fabrication for HCI

Fall: 12 units

This course will consider how new fabrication techniques such as 3D printing, laser cutting, CNC machining and related computer controlled technologies can be applied to problems in Human-Computer Interaction. Each offering will concentrate on a particular application domain for its projects. This year the course will consider assistive technology. This course will be very hands-on and skills-oriented, with the goal of teaching students the skills necessary to apply these technologies to HCI problems such as rapid prototyping of new device concepts. To this end? Every student in this course will build and take home a 3D printer. (There will be \$400-\$500 cost associated with this course to make that possible. Details on this are still to be determined.)

05-436 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

Course Website: <http://www.hcii.cmu.edu/courses/usuable-privacy-and-security> (<http://www.hcii.cmu.edu/courses/usuable-privacy-and-security/>)

05-439 The Big Data Pipeline: Collecting and Using Big Data for Interactive Systems

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <http://data.cmu.edu>

05-440 Interaction Techniques

Intermittent: 12 units

This course will provide a comprehensive study of the many ways to interact with computers and computerized devices. An "interaction technique" starts when the user does something that causes an electronic device to respond and includes the direct feedback from the device to the user. Examples include physical buttons and switches, on-screen menus and scroll bars operated by a mouse, touch screen widgets and gestures such as flick-to-scroll, text entry on computers or touch screens, game controllers, interactions in 3D and virtual/augmented reality, consumer electronic controls such as remote controls, and adaptations of all of these for people with disabilities. We will start with a history of the invention and development of these techniques, discuss the various options used today, and continue on to the future with the latest research on interaction techniques presented at conferences such as ACM CHI and UIST. Appropriate design and evaluation methods for interaction techniques will also be covered. Guest lectures from inventors of interaction techniques are planned. Students will have a choice for final projects that can focus on historical or novel interaction techniques.

Course Website: <http://www.cs.cmu.edu/~bam/uicourse/05440inter/>

05-452 Service Design

Fall: 12 units

In this course, we will collectively define and study services and product service systems, and learn the basics of designing them. We will do this through lectures, studio projects, and verbal and written exposition. Classwork will be done individually and in teams.

05-470 Digital Service Innovation

Intermittent: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-499 Special Topics in HCI

Fall and Spring: 12 units

Special Topics in HCI is an opportunity for students interested in HCI to gain a deeper understanding of a specific area in this field. Each class is designed to cover an emerging research area within HCI, from designing large-scale peer learning systems to designing games around audience agency. All sections will help students: (1) build a more comprehensive understanding of an area of study within HCI, (2) work closely with faculty and peers to create mini-projects or team assignments that help students master the course material, (3) explore evidence-based research methods and techniques in HCI. Sections will vary in topic and often change from semester to semester. Because of this, students can take multiple sections, as they are individual classes. Undergraduate sections are listed as 499 and graduate sections are listed as 899. For descriptions of specific sections for this academic year, visit the "Courses" section on the Human-Computer Interaction Institute website.

Course Website: <http://www.hcii.cmu.edu/academics/courses> (<http://www.hcii.cmu.edu/academics/courses/>)

05-540 Rapid Prototyping of Computer Systems

Spring: 12 units

This is a project-oriented course, which will deal with all four aspects of project development: the application, the artifact, the computer-aided design environment, and the physical prototyping facilities. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time. Upon completion of this course the student will be able to: generate systems specifications from a perceived need; partition functionality between hardware and software; produce interface specifications for a system composed of numerous subsystems; use computer-aided development tools; fabricate, integrate, and debug a hardware/software system; and evaluate the system in the context of an end user application. The class consists of students from different disciplines who must synthesize and implement a system in a short period of time.

Course Website: <http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems> (<http://www.hcii.cmu.edu/courses/rapid-prototyping-computer-systems/>)

05-571 Undergraduate Project in HCI

Spring: 12 units

Experiential learning is a key component of the MHCI program. Through a substantial team project, students apply classroom knowledge in analysis and evaluation, implementation and design, and develop skills working in multidisciplinary teams. Student teams work with Carnegie Mellon University-based clients or external clients to iteratively design, build and test a software application which people directly use.
Prerequisites: 05-610 Min. grade B or 05-431 Min. grade B or 05-630 Min. grade B or 05-631 Min. grade B or 05-410 Min. grade B or 05-430 Min. grade B

Course Website: <http://www.hcii.cmu.edu/courses/undergraduate-project-hci> (<http://www.hcii.cmu.edu/courses/undergraduate-project-hci/>)

05-589 Independent Study in HCI-UG

All Semesters

In collaboration with and with the permission of the professor, undergraduate students may engage in independent project work on any number of research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, complete a contract, and present a tangible deliverable. The Undergraduate Program Advisor's signature is required for HCI undergraduate-level Independent Study courses. Registration is through the HCII Undergraduate Programs Manager only.

05-600 HCI Pro Seminar

Fall: 6 units

This course is only for MHCI students. This course is specifically built to expose students to the world of HCI through research and industry talks, as well as strengthening HCI communication skills for work in industry. Seminar Component: To expose students to the world of HCI through research and industry expert talks with written assignments. Conflict Management Component: To educate students on conflict management, teamwork, active listening skills, and communication skills in order to give them tools to collaborate and work more efficiently on multi-disciplinary teams. Professional Series Component: To expose students to the world of HCI through guest speakers, prepare students to navigate job hunting through resume and portfolio workshops and to provide industry insights into HCI and the profession through guest speakers and panel discussions.

Course Website: <http://www.hcii.cs.cmu.edu>

05-602 IDEATe: Learning in Museums

Spring: 12 units

Learning in Museums brings together students from across the disciplines to consider the design of mediated learning experiences in a project-based inquiry course. Students will be introduced to a range of design research methods and associated frameworks that explore the cognitive, social and affective dimensions of learning in everyday contexts through readings, invited lectures, in-class activities and assignments. Students will conduct a series of short design research studies to define learning goals and develop supporting design concepts intended to improve learning outcomes for diverse participants in informal learning settings (e.g. museums, after-school programs, maker spaces or online). In concept development, we will look at how to position technology and question its role in the setting to engage and foster positive learning interactions and conversation. This semester we will be working with the Carnegie Museum of Natural History as our primary stakeholder. The course will culminate in a media-rich presentation of design concepts and a fielded prototype to a review panel and include a piloted evaluation plan describing how learning outcomes for the project would be assessed. In consultation with the instructor, students in the graduate section of the course will be assigned an HCI/learning research literature review and presentation related to their project topic.

05-610 User-Centered Research and Evaluation

Fall: 12 units

This course provides an overview and introduction to the field of human-computer interaction (HCI). It introduces students to tools, techniques, and sources of information about HCI and provides a systematic approach to design. The course increases awareness of good and bad design through observation of existing technology, and teaches the basic skills of generative and evaluative research methods. This is a companion course to software implementation (05-430, 05-431 05-380). When registering for this course, undergraduate students are automatically placed the wait list. Students will be then moved into the class, based on if they are in the BHCI primary or second major and year in school e.g. seniors, juniors, etc. Freshman are not permitted to register in this course. In the Fall, this course is NOT open to students outside the HCI major or MHCI. The Spring offering is open to all students. This course is a core requirement for students in the HCI additional major and the MHCI program.

Course Website: <http://www.hcii.cs.cmu.edu>

05-615 Persuasive Design

Fall: 12 units

This project-based course focuses on the ethical, human-centered design and evaluation of persuasive technologies that aim to change users' attitudes, emotions, or behaviors in ways that benefit the self and/or society. In addition to exposing students to an array of psychological theories and strategies for implicit and explicit persuasion, the course will cover a variety of topics illustrating both the pitfalls and possibilities in designing for positive impact in HCI. The focal point of the class will be the semester project, for which student teams will iteratively conceptualize, prototype, implement, and evaluate a tool, system, or change to a ubiquitous computing environment that intends to stimulate and sustain belief or behavior change (such as reducing cognitive or social biases, building healthy or prosocial habits, or resisting other persuasive forces one encounters on a daily basis).

05-618 Human AI Interaction

Intermittent: 12 units

Artificial Intelligence is inspired by human intelligence, made powerful by human data, and ultimately only useful in how it positively affects the human experience. This course is an introduction to harnessing the power of AI so that it is beneficial and useful to people. We will cover a number of general topics: agency and initiative, AI and ethics, bias and transparency, confidence and errors, human augmentation and amplification, trust and explainability, mixed-initiative systems, and programming by example. These topics will be explored via projects in dialog and speech-controlled systems, automatic speech recognition, computer vision, data science, recommender systems, text summarization, learning science, UI personalization, and visualization. Students will complete individual weekly mini-projects in which they will design and build AI systems across a wide variety of domains. Students should be comfortable with programming; assignments will be primarily in Python and Javascript. Prior experience with AI/machine learning will be useful but is not required. Students will also be responsible for weekly readings and occasional presentations to the class.

Course Website: <https://www.hcii.cmu.edu/academics/courses> (<https://www.hcii.cmu.edu/academics/courses/>)

05-619 Data Visualization

Fall: 12 units

This course is an introduction to key design principles and techniques for interactively visualizing data. The major goals of this course are to understand how visual representations can help in the analysis and understanding of complex data, how to design effective visualizations, and how to create your own interactive visualizations using modern web-based frameworks.

Course Website: <https://dig.cmu.edu/courses/2022-fall-datavis.html>

05-650 Interaction Design Studio II

Spring: 12 units

This course follows Interaction Design Fundamentals (05-651). Students are expected to apply what they have learned about design thinking and methodologies as a starting point for all assignments. Students will work in teams to perform guerrilla research, synthesize data, and consider the needs of multiple stakeholders in their design of mobile services and other intelligent systems. Design concepts go beyond user interfaces to include sensors, controls, and ubiquitous computing. Emphasis is placed on the quality of the students ideas and their ability to give form to their design concepts. By completing and presenting their work, students will gain skills related to professional UX design practice.

Prerequisite: 05-651

Course Website: <http://www.hcii.cmu.edu/courses/interaction-design-studio> (<http://www.hcii.cmu.edu/courses/interaction-design-studio/>)

05-651 Interaction Design Studio I

Fall: 12 units

This studio course introduces students to design thinking and the basic practices of interaction design. We follow a human-centered design process that includes research, concept generation, prototyping, and refinement. Students must work effectively as individuals and in small teams to design mobile information systems and other interactive experiences. Assignments approach design on three levels: specific user interactions, contexts of use, and larger systems. Students will become familiar with design methodologies such as sketching, storyboarding, wire framing, prototyping, etc. No coding is required. This course serves as a prerequisite for Interaction Design Studio (05-650). Students who are required to take this course have priority and will be enrolled first.

05-660 Interaction Design Fundamentals

Fall and Spring: 12 units

IXD Fundamentals introduces the human-centered design process as well as fundamental interaction design principles, methods, and practices. The course is for both students who may only enroll in one interaction design course and those who intend to build upon their HCI learning by taking advanced interaction design courses. Students must work effectively as individuals and in small teams to learn interaction design concepts and apply them to real-world problems. By the end of this course students should be able to; -Apply appropriate interaction design methods in a human-centered design process. -Create persuasive interim and final design artifacts that demonstrate communication design fundamentals. -Facilitate productive and structured critique across the class and with instructors. - Explain and apply fundamental interaction design principles. -Create clarity and readability in artifacts, including GUIs and deliverables, through the disciplined application of visual design principles such as typography, color and composition. -Practice reframing a given problem in order to create opportunities that drive generating multiple solutions. -Demonstrate habits that foster the creative process, including drawing, divergent thinking, and creative experimentation. -Identify and explore with interaction design materials. This course serves as a prerequisite for Advanced Interaction Design Studio (number TBD). Students who are required to take this course have priority and will be enrolled first. No coding is required.

05-661 Advanced Interaction Design

Spring: 12 units

Advanced Interaction Design (05-361/05-661) follows Interaction Design for Human-Computer Interaction (05-360/05-660). Students are expected to build on the basic interaction design principles they learned in Interaction Design for Human-Computer Interaction by applying advanced methods to solve more complex problems using emerging technologies in user experiences that cross devices, modalities and contexts. Students learn how to design with advanced technologies that predict, assist and automate, and make through a design system. Systems thinking, data as a design material, and UI design are emphasized in projects which are designed to give students experience solving complex problems that they are likely to encounter as practitioners. Advanced Interaction Design prepares students to become interaction designers that take a rigorous and principled approach to solving enterprise-scale problems where many systems and applications serve many stakeholders.

05-670 Digital Service Innovation

Fall: 12 units

Attention entrepreneurs, designers, and engineers! This course teaches you to invent digital services. You will learn about value-creation in the service sector and a human-centered design process including brainstorming, storyboarding, interviewing, video sketches, and pitching. Students work in small, interdisciplinary teams to discover unmet needs of users. They conceive of a digital service and assess its technical feasibility, financial viability, and desirability. Then they produce a plan with a business model and a video sketch and pitch it to industry professionals. Grades will be determined primarily by the quality of the team's products.

05-674 Ethics and Policy Issues in Computing

Intermittent: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

05-680 Independent Study in HCI - METALS

All Semesters

With the permission of the professor, METALS students may engage in independent project work on any number of innovative research projects sponsored by faculty. Students must complete an Independent Study Proposal, negotiate the number of units to be earned, submit a contract, and present a tangible deliverable. The Program Advisor's signature is required for the METALS Independent Study course.

05-685 Prototyping Algorithmic Experiences

Intermittent: 15 units

This project-based course provides an overview and hands-on introduction to iterative prototyping methods in HCI, with an emphasis on current and emerging technologies such as data-driven algorithmic systems, AI and machine learning, spatial computing, and IoT. Students will learn and implement approaches for creating and using prototypes to iteratively inform the creation of new technologies. The course will help students learn to strategically evaluate whether a given prototyping approach is a good fit for a given design or research question. In addition to HCI undergraduate majors, the course is open to undergraduate and graduate level students with proficiency in programming and prior courses or experience in user-centered research, design, and/or evaluation. Some exceptions to the course prerequisites will be granted with the permission of the instructor. Prerequisites: 15-112 and (15-121 or 15-150 or 15-210 or 15-122) and (05-891 or 05-610) and (05-651 or 05-650 or 05-652 or 05-617 or 05-670)

05-738 Evidence-Based Educational Design

Fall: 12 units

The aim of this course is to teach students how to develop educational goals based on a detailed task analysis of the knowledge, skills, and dispositions required for mastery of a particular aspect of a domain. Goals for early childhood, elementary, middle school, high school, postsecondary, and adult education will be discussed and related to relevant state, national, and international standards. A comprehensive understanding of student achievement will be developed. The importance of matching the instructional program and its assessment to goals will be discussed and demonstrated. Assessment that focuses on covering the full range of specified goals will be studied along with diverse approaches for valid assessment. Other topics include making instructional material choices, funding, classroom management, ethics, schools, and social systems. Assignments will emphasize linking goals - instruction - assessment. A term project will consist of an in-depth study of one central unit in a discipline or grade level. Undergraduates are invited to take this course with special permission from Dr. Lauren Hercik.

05-823 E-Learning Design Principles and Methods

Fall: 12 units

This course is about e-learning design principles, the evidence and theory behind them, and how to apply these principles to develop effective educational technologies. It is organized around the book "e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning" by Clark and Mayer with further readings drawn from cognitive science, educational psychology, and human-computer interaction. You will learn design principles 1) for combining words, audio, and graphics in multimedia instruction, 2) for combining examples, explanations, practice and feedback in online support for learning by doing, and 3) for balancing learner versus system control and supporting student metacognition. You will read about the experiments that support these design principles, see examples of how to design such experiments, and practice applying the principles in educational technology development.

Course Website: http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013#Course_Details (http://www.learnlab.org/research/wiki/index.php/E-learning_Design_Principles_2013/#Course_Details)

05-839 Interactive Data Science

Spring: 12 units

This course covers techniques and technologies for creating data driven interfaces. You will learn about the entire data pipeline from sensing to cleaning data to different forms of analysis and computation.

Course Website: <https://hcii.cmu.edu/academics/courses> (<https://hcii.cmu.edu/academics/courses/>)

05-840 Tools for Online Learning

Fall: 12 units

In this course, we will explore issues that pertain to interaction and interface design. The class will focus on elements of the larger interaction design process including basic design principles, information architecture and navigation, planning and brainstorming methods, and techniques for developing rapid sketches and prototypes. Course Requirements: This class will not focus on learning specific software tools. Students are expected to have prior experience using a variety of design and programming tools. Please speak with the instructor if you have questions regarding these prerequisites. This course was design for students in the METALS program.

Software Societal Systems Courses**17-200 Ethics and Policy Issues in Computing**

Fall and Spring: 9 units

Should autonomous robots make life and death decisions on their own? Should we allow them to select a target and launch weapons? To diagnose injuries and perform surgery when human doctors are not around? Who should be permitted to observe you, find out who your friends are, what you do and say with them, what you buy, and where you go? Do social media and personalized search restrict our intellectual horizons? Do we live in polarizing information bubbles, just hearing echoes of what we already know and believe? As computing technology becomes ever more pervasive and sophisticated, we are presented with an escalating barrage of decisions about who, how, when, and for what purposes technology should be used. This course will provide an intellectual framework for discussing these pressing issues of our time, as we shape the technologies that in turn shape us. We will seek insight through reading, discussion, guest lectures, and debates. Students will also undertake an analysis of a relevant issue of their choice, developing their own position, and acquiring the research skills needed to lend depth to their thinking. The course will enhance students' ability to think clearly about contentious technology choices, formulate smart positions, and support their views with winning arguments.

17-210 Introduction to Social Networks

Spring: 12 units

Course Description What makes a recommendation system on social media effective? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet we have not heard of most of them? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of the free flow of information and fluid connectivity between people that these platforms had envisioned? How do professionals land their dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of social connections that people form on and offline. This course offers an introduction to the study of social networks as a powerful tool for understanding a wide range of questions and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network concepts and their mathematical operationalizations that give social network analysis the versatility for rigorous quantitative analysis. Students will subsequently learn how these building blocks have been applied to analyze and solve a wide range of online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms. Throughout this course, students will work towards a final team project that applies network concepts and measures to either (a) describe and/or explain an empirically puzzling social phenomenon with network data, (b) develop a network data collection pipeline that aims to solve a real-world problem, or (c) build a system utilizing the insights from the course that solves a real-world problem. The following class activities throughout the course are intended to support and augment the final project.

17-213 Network Analysis: The Hidden Structures behind the Webs We Weave

Fall: 12 units

Have you wondered how Linux and the subsequent development of open-source software ecosystems could thrive despite weak economic incentives? Why do large-scale complex software systems sometimes fail despite well-developed guardrails and practices? What makes a recommendation system on social media so effective and so toxic at the same time? Why do YouTube mega-influencers with tens of millions of subscribers exist, yet each of us only recognize a handful of them at best? Why do echo chambers form and polarization deepen in social media platforms despite the utopian promise of frictionless connectivity that these platforms initially envisioned? How can you land your dream jobs? How does mass adoption of technological innovations happen (e.g., Python, Bitcoin)? Underlying these seemingly unrelated questions is the powerful influence of social networks, the collection of on- and offline social connections, communications, and collaborations that people form with one another. This course offers an introduction to the study of social networks as a powerful tool for formalizing these wide range of questions, for understanding social dynamics in various settings, and for solving real-world problems arising at the intersection of human social behavior and technological systems. The course first introduces network science concepts and their mathematical operationalizations that give rigorous definitions to fuzzy words we use to describe the social world, such as "status" and "social group". Students will subsequently learn how these network concepts were used to analyze and solve a wide range of puzzling online social phenomena. Finally, the course will introduce statistical models of networks that enable principled investigation of network formation mechanisms.

17-214 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.

Prerequisites: (15-122 Min. grade C or 15-121 Min. grade C) and (21-127 Min. grade C or 21-128 Min. grade C or 15-151 Min. grade C)

Course Website: <https://www.cs.cmu.edu/~ckaestne/17214/f2021/>

17-224 Influence, Persuasion, and Manipulation Online

Fall: 9 units

This course will introduce the fundamental behavioral science of influence, persuasion, and manipulation, and the application of these scientific principles to online campaigns to influence attitudes and behavior. In particular, we will discuss the psychology of persuasion, nudging, social influence, bias, persuasive design, and the ethics of persuasion. Against this background, we will analyze case studies drawn from recent, high profile events such as election campaigns, targeted advertising, sowing political division, memes and virality, impact of social media, and propagation of "fake news." Countermeasures to these tactics will be explored, including personal measures, technologies, and policy.

17-301 Special Topics in Societal Computing: Understanding Cyber Teams

Intermittent: 9 units

Were you the victim of a ransomware attack today? No? Then you should probably thank your cyber security team! Nowadays, nearly everything modern organizations do is protected by some semblance of a cyber team. These cyber teams come in many forms: security operations center, malware analysis, threat emulation, information technology departments, etc. So what do we know about how these cyber teams operate? In this course cyber teams will be studied through the lens of computational organization theory. Different types of cyber teams will be presented with how they operate within the organization. An array of computational organization theory principles will be explored such as network science, information diffusion, policy analysis, and performance theory. A final project will be completed by each student. This project can be of many types such as policy analysis, virtual experimentation, dynamic network analysis, validation, etc. Students will be using the NetLogo scripting language to complete a project. The project will be created, developed, and presented by the student and approved by the instructor.

17-302 Independent Study Mini Undergraduate

Intermittent

Independent Study Mini

17-303 Cryptocurrencies, Blockchains and Applications

Fall and Spring: 9 units

Cryptocurrencies such as Bitcoin have gained large popularity in recent years, in no small part due to the fantastic potential applications they could facilitate. This course will first provide an overview of the technological mechanisms behind cryptocurrencies and distributed consensus and distributed ledgers ("blockchains"), introducing along the way the necessary cryptographic tools. It will then focus on more advanced blockchain applications, such as "smart contracts," that is, contracts written as code. Finally, the course will also introduce some of the legal and policy questions surrounding cryptocurrencies.

17-313 Foundations of Software Engineering

Fall and Spring: 12 units

Students gain exposure to the fundamental principles of software engineering. This includes both core CS technical knowledge and the means by which this knowledge can be applied in the practical engineering of complex software in real-world settings. Topics related to software artifacts include coding, software architecture, measurement, and quality assurance of various qualities (e.g., robustness, security, performance, maintainability) with static and dynamic analysis, testing, code review, and inspection. Topics related to software process include requirements engineering, process models and evaluation, personal and team development, and supply chain issues including outsourcing and open source. This course has a strong technical focus, a strong focus on developing team skills, and will include both written and programming assignments. Students will get experience with the latest software engineering tools and practices.

Course Website: <https://www.cs.cmu.edu/~ckaestne/17313/>

17-314 Formal Methods

Fall: 6 units

Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction.

17-322 Agile Methods

Fall: 6 units

Agile methods refers to a number of software development approaches that adopt self-organization, adaptive planning, evolutionary development, frequent delivery and working closely with and incorporating feedback from customers throughout the development process as their principles of operation to achieve responsiveness. This course will introduce students to two well known agile methods: Scrum and Kanban, connecting their practices to established group dynamics and knowledge management theories to explain why they work and under what circumstances

17-323 Quality Assurance

Fall: 6 units

This class is fundamentally about software quality assurance and control. This course will introduce various quality assurance tools and techniques to software engineering students. Students will build their "quality toolbox" not only with useful tools and techniques, but with the knowledge of when those tools should be used, how to evaluate their results, and what assurances they can provide. The key learning objectives of the course include: 1. Understand software quality: how to define it, analyze it, and measure it. 2. Select the proper analytical tool/technique for a given situation and explore how to analyze results. 3. Understand the strengths and weaknesses of different quality assurance techniques, such as software testing, static analysis, code review, and demonstration. 4. Learn to collect, manage, and evaluate quality metrics. 5. Analyze and verify a variety of software properties including, but not limited to, functionality, security, reliability, and performance. 6. Gain experience with real quality assurance tools including static analysis tools, software testing frameworks, and software quality measurement tools

17-324 Advanced Formal Methods

Fall: 6 units

This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures, 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

Prerequisite: 17-314 Min. grade B

17-331 Information Security, Privacy, and Policy

Fall: 12 units

As layers upon layers of technology mediate increasingly rich business processes and social interactions, issues of information security and privacy are growing more complex too. This course takes a multi-disciplinary perspective of information security and privacy, looking at technologies as well as business, legal, policy and usability issues. The objective is to prepare students to identify and address critical security and privacy issues involved in the design, development and deployment of information systems. Examples used to introduce concepts covered in the class range from enterprise systems to mobile and pervasive computing as well as social networking. Format: Lectures, short student presentations on topics selected together with the instructor, and guest presentations. Target Audience: Primarily intended for motivated undergraduate and masters students with CS background. Also open to PhD students interested in a more practical, multi-disciplinary understanding of information security and privacy.

17-332 Software Project Management

Spring: 6 units

Projects are temporary organizations set up to achieve a one time objective in an agreed time frame. They are characterized by requiring the execution of interrelated, normally non repeating activities, by multidisciplinary groups. Because of its temporary nature and the interrelatedness of its activities, projects require prescriptive planning, budgeting, staffing and risk management. This course will introduce student to fundamental project management techniques and tools such as activity planning, milestone planning, estimation, work breakdown structures, critical paths. The course will also look at hybrid methods such as Milestone Driven Agile Execution and Disciplined Agile Delivery.

17-333 Privacy Policy, Law, and Technology

Fall: 9 units

This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-334 Usable Privacy and Security

Spring: 9 units

There is growing recognition that technology alone will not provide all of the solutions to security and privacy problems. Human factors play an important role in these areas, and it is important for security and privacy experts to have an understanding of how people will interact with the systems they develop. This course is designed to introduce students to a variety of usability and user interface problems related to privacy and security and to give them experience in designing studies aimed at helping to evaluate usability issues in security and privacy systems. The course is suitable both for students interested in privacy and security who would like to learn more about usability, as well as for students interested in usability who would like to learn more about security and privacy. Much of the course will be taught in a graduate seminar style in which all students will be expected to do a weekly reading assignment and each week different students will prepare a presentation for the class. Students will also work on a group project throughout the semester. The course is open to all graduate students who have technical backgrounds. The 12-unit course numbers (08-734 and 5-836) are for PhD students and masters students. Students enrolled in these course numbers will be expected to play a leadership role in a group project that produces a paper suitable for publication. The 9-unit 500-level course numbers (08-534 and 05-436) are for juniors, seniors, and masters students. Students enrolled in these course numbers will have less demanding project and presentation requirements.

17-335 Software Architectures

Spring: 6 units

Successful design of complex software systems requires the ability to describe, evaluate, and create systems at an architectural level of abstraction. This course introduces architectural design of complex software systems. The course considers commonly-used software system structures, techniques for designing and implementing these structures, models and formal notations for characterizing and reasoning about architectures, tools for generating specific instances of an architecture, and case studies of actual system architectures. It teaches the skills and background students need to evaluate the architectures of existing systems and to design new systems in principled ways using well-founded architectural paradigms. After completing this course, students will be able to: 1. describe an architecture accurately 2. recognize major architectural styles in existing software systems 3. generate architectural alternatives for a problem and choose among them 4. construct a medium-sized software system that satisfies an architectural specification 5. use existing definitions and development tools to expedite such tasks 6. understand the formal definition of a number of architectures and be able to reason about the properties of those architectures 7. use domain knowledge to specialize an architecture for a particular family of applications.

17-336 Applied Distributed Systems

Spring: 6 units

Modern computing systems are frequently hosted on the cloud. That is, they are inherently distributed systems. To appropriately build and deploy these systems developers should know not only about development tools such as container management tools but also the structure of the cloud - in particular how it utilizes virtual machines, containers and networks. They should also understand security mechanisms both in the internet and how to authorize users and maintain credentials securely. Finally, to protect the system once it is placed into production, a developer needs to know how to enable the detection of problems during execution through collection and navigation of logs produced by the system. These are the topics covered by this course.

17-340 Green Computing

Intermittent: 9 units

Note: Previously offered as 08-340. Energy is a key societal resource. However, our energy usage is rising at an alarming rate and therefore it has become critical to manage its consumption more efficiently for long term sustainability. This course introduces students to the exciting area of "Green Computing", and is organizationally divided into two tracks. The first track is "Energy-Efficient Computing", which considers the state of the art techniques for improving the energy efficiency of mobile devices, to laptop and desktop class computers and finally to data centers. We will cover energy efficiency across the hardware/software stack, starting from the individual components like processors and radio interfaces to system level architectures and optimizations. The second track is "Applying Computing towards Sustainability", covering topics that leverage computing to reduce the energy footprint of our society. In particular, we will focus on Smart Buildings and the Smart Grid, covering topics such as sensing, modeling and controlling the energy usage of buildings, new operating systems or software stacks for the smart infrastructure, as well as the privacy and security issues with the new "internet of things". The goal of this course is to help students acquire some of the knowledge and the skills needed to do research in this space of "Green Computing". Although the course is listed within SCS, it should be of interest to students in several departments, including ECE, MechE, CEE, EPP and Architecture.

17-346 DevOps and Continuous Integration

Spring: 6 units

DevOps: Engineering for Deployment and Operations": DevOps is the term given to a modern movement to establish practices that significantly reduce the time to production of committed code. This time involves deployment - the period between the completion of the code by the developers and the placing of the code into normal production and dealing with operations issues. Deployment time can be days, weeks, or even months when using normal development practices. Operational issues such as dealing with incidents and errors introduce other delays. Modern internet companies deploy a system multiple or even dozens of times every day. Achieving this velocity requires coordinated process and design activities together with supporting tooling. This course will cover the deployment process and the associated tooling, it will highlight reasons why release schedules can be slow, and it will introduce the practices that are used to enable high velocity deployments. It will also cover the kinds of problems that are created because of high velocity and how modern internet companies deal with these problems. Please note: This is a required course for MSE-SS students. Students outside of the software engineering department may take this course but students of the MSE programs will have first priority. Prerequisite: 17-336 Min. grade B

17-350 Information Technology Policy: Evidence, Communication, & Advocacy

Spring: 9 units

In recent decades, developments in Information and Communication Technologies (ICTs) have rapidly moved from research environments to products and services used by billions of people. This rapid rate of change has often resulted in a public which does not understand the technologies shaping their lives and lawmakers who are poorly equipped to make sound policy. It is therefore incumbent upon specialists to communicate how ICTs work to the public and lawmakers so policy making is shaped by evidence and reflects public desires. This course will train students to be effective communicators and advocates in the ICT space. Students taking this course will learn about the broader scope of technology policymaking including formal lawmaking, agency rule-making, strategic litigation, and corporate social responsibility. Current ICT policy topics in privacy, free expression, net neutrality, and competition will be covered. Public communication strategies such as writing op-eds, interviewing with journalists, producing explanatory videos and interactive games will be explored. Finally, students will learn how to perform an expert role in areas such as writing policy briefs and providing testimony. The course is open to advanced undergraduate and graduate students. Graduate students whose research has public policy implications are encouraged to develop projects related to their research. There is no requirement for programming knowledge, but students with experience in developing interactive media and games will be encouraged to utilize such skills. The class will focus heavily on readings, critical evaluation of real ICT advocacy campaigns, and homework will provide hands-on experience with numerous strategies for public engagement. At the end of the semester students will have a portfolio of projects which they may release publicly.

17-355 Program Analysis

Spring: 12 units

This course covers both foundations and practical aspects of the automated analysis of programs, which is becoming increasingly critical to find software errors and assure program correctness. The theory of abstract interpretation captures the essence of a broad range of program analyses and supports reasoning about their correctness. Building on this foundation, the course will describe program representations, data flow analysis, alias analysis, interprocedural analysis, dynamic analysis, Hoare Logic and verification, program synthesis and repair, model checking, and symbolic execution. Through assignments and projects, students will design and implement practical analysis tools that find bugs and verify properties of software. This course satisfies the Logic and Languages constrained elective category of the Computer Science major, the Theoretical Foundations requirement of the Computer Science master's degree, and the Technical Software Engineering requirement for the Software Engineering minor. Prerequisites: 15-251 Min. grade C and (15-150 Min. grade C or 17-214)

Course Website: <https://cmu-program-analysis.github.io/>**17-356 Software Engineering for Startups**

Spring: 12 units

Startup engineering is critical to innovation. The skills required to effectively prototype, launch, and scale products are vital to engineers everywhere, from fledgling companies founded in dorm rooms to local mid-size companies to internal startups from multi-national tech giants. However, developing software in a startup environment poses unique engineering challenges. These challenges include making and justifying foundational architectural and technical decisions despite extreme uncertainty; rapidly prototyping and evaluating new ideas and features, while building minimum viable products; prioritizing engineering effort in severely constrained environments; and communicating effectively both within a small engineering team and with internal and external non-technical stakeholders. This course teaches the skills necessary to engineer successfully in a startup environment, through lectures, group projects, case study discussions, and guest speakers drawn from experienced, practicing startup engineers. This is an engineering-focused course; no entrepreneurship background is required or expected. Students do not need to have a startup idea to participate fully. Prerequisites: 15-213 or 17-514 or 17-214 or 15-214

17-363 Programming Language Pragmatics

Fall: 12 units

This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll. Prerequisites: 15-150 Min. grade C and (15-251 Min. grade C or 21-228 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-363/>**17-396 Language Design and Prototyping**

Spring: 12 units

Many programmers think of programming languages as having a fixed, standard set of features and #8212;but in fact, languages are being extended all the time, and new languages are constantly being developed, providing great expressive power. In this course, students will learn about techniques for designing and prototyping programming languages. Design topics include language features, a practical approach to semantics, conceptual design techniques, and examples of both general purpose and domain-specific language designs. Prototyping topics include interpreters, source-to-source translators, languages as libraries, and paper prototyping techniques used for lightweight user evaluations. In course assignments, students will practice design and prototyping techniques, implementing prototype languages in several different styles. The course will end with a project in which students design, implement, and evaluate their own programming language. Prerequisites: 17-514 or 15-213 or 17-214

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-396/>

17-397 Intro to Qualitative Research: Social Media Apps and Video Content Creation

Spring: 12 units

Short-video apps, such as TikTok, have revealed themselves to be highly accessible and increasingly ubiquitous in regards to online social interaction and are currently the most popular social media among mostly young(er) users. This course focuses on how humans as users interact with and understand social technology and how the use of social media apps is connected to and integrated into our everyday life by asking questions like: What are users' motivations to participate in video creation and sharing on social media? What are their practices, strategies, and routines in creating short-form videos as part of digital online culture? What do they know about socio-technical aspects in using short-video apps and creating short-form video content? How does their understanding of socio-technological aspects influence their use of social media apps? This course is designed to enable students to develop and conduct their own individual research project. For this, students will learn how to design, conduct, and analyze qualitative interviews to research socio-technical, cultural, and political perspectives of usage of and engagement with short-form videos and short-video apps, such as TikTok. The course instructor will closely mentor and supervise students' research projects throughout the semester and will provide expertise and background in qualitative methods and social media research to guide students through the research process.

17-400 Machine Learning and Data Science at Scale

Fall and Spring: 12 units

Datasets are growing, new systems for managing, distributing, and streaming data are being developed, and new architectures for AI applications are emerging. This course will focus on techniques for managing and analyzing large datasets, and on new and emerging architectures for applications in machine learning and data science. Topics include machine learning algorithms and how they must be reformulated to run at scale on petabytes of data, as well as data management and cleaning techniques at scale. In addition to large-scale aspects of data science and machine learning, this course will also cover core concepts of parallel and distributed computing and cloud computing, including hands-on experience with frameworks like Spark, streaming architectures like Flink or Spark Streaming, MLlib, TensorFlow, and more. The course will include programming assignments and a substantial final project requiring students to get hands-on experience with large-scale machine learning pipelines or emerging computing architectures.

Prerequisites: 10-601 or 10-701 or 15-211 or 10-301 or 17-514 or 17-214 or 15-214

Course Website: <http://euro.ecom.cmu.edu/program/courses/tcr17-803>
(<http://euro.ecom.cmu.edu/program/courses/tcr17-803/>)

17-401 Software Engineering for AI-Enabled Systems

Fall: 12 units

New Course Need Description

Course Website: <https://ckaestne.github.io/seai/>

17-402 AI and Emerging Economies

Intermittent: 3 units

The course will cover some of the unique aspects of emerging economies as it relates to AI consumption and responsible AI development. The importance of local data and domain knowledge will be illustrated. Germane to budding technologists, entrepreneurs and policy influencers. Multi-disciplinary.

17-405 Grand Challenges in AI: Past, Present and Future

Intermittent: 3 units

Innovative, bold initiatives that capture the imagination of researchers and system builders are often required to spur a field of science or technology forward. A vision for the future of artificial intelligence was laid out by Turing Award winner and Moza Bint Nasser University Professor at CMU, Raj Reddy in his 1988 Presidential address to the Association for the Advancement of Artificial Intelligence. It is time to provide an accounting of the progress that has been made in the field, over the last three decades, toward the challenge goals. While some tasks such as the world-champion chess machine were accomplished in short order, many others, such as self-replicating systems, require more focus and breakthroughs for completion. A new set of challenges for the current decade is also proposed, spanning the health, wealth, and wisdom spheres. The above - plus commentary from half a dozen AI thought leaders - forms the basis of an article in the 2021 Spring Issue of AI Magazine.

17-413 Software Engineering Practicum

Spring: 12 units

This course is a project-based course in which students conduct a semester-long project for a real client in small teams. This is not a lecture-based course; after the first few weeks the course consists primarily of weekly team meetings with the course instructors, with teams making regular presentations on their software development process. Students will leave the course with a firsthand understanding of the software engineering realities that drive SE practices, will have concrete experience with these practices, and will have engaged in active reflection on this experience. After the course, students will have the teamwork, process, and product skills to be immediately competent in a software engineering organization, and will be able to evaluate the new processes and techniques they will encounter in the workplace.

17-415 Software Engineering Reflection

Fall: 6 units

This course is an opportunity to reflect on a software engineering experience you have had in industry. It is structured as a writers workshop, in which you will work with the instructor and other students to identify and flesh out a software engineering theme that is illustrated by your industry experience. You will prepare a 10-page report on this theme, comparable to a practitioner's report at a conference like ICSE or OOPSLA, and a 30-minute presentation to match. This course fulfills a requirement of the Software Engineering Minor program, but students in other programs may take the course if they meet the prerequisite industry experience and if space is available.

17-422 Building User-Focused Sensing Systems

Fall and Spring: 12 units

These days we are surrounded by sensing and computation. Smart devices, such as smartphones, smartwatches, are packed with sensors. While they are already very useful devices, we have only started to scratch the surface here. The aim of this class will be to introduce the students to building and understanding smart sensing devices. The course will include discussion into contribution of various fields, including human-computer interaction, embedded computing, computer vision, distributed systems, machine learning, signal processing, security, and privacy. We will discuss how these various disciplines are coming together to form an end-to-end system that generates useful and user-actionable data. We will take a hands-on approach towards building and evaluating these systems. The students will gain practical experience in developing sensing systems in different application domains, such as activity recognition, health sensing, gestural interaction, etc. You will learn about embedded systems and understand the advantages and limitations of different platforms. You will learn about sensors and how to interface them with the real world to be able to get useful and actionable data. You will learn how to build a network of sensors that can communicate with each other. You will also learn about storing the sensor data for visualization, analysis and presentation both locally and to the cloud. The course will be a combination of lectures, tutorials, class discussions, and demonstrations. Students will be evaluated based on 5 mini-projects/assignments, class participation, weekly reading summaries, and a final project. All hardware resources will be provided to the students and they will be given an option to take their final prototypes with them for the cost of the hardware components. Students should have reasonable programming experience and an interest in tinkering.

17-428 Machine Learning and Sensing

Fall: 12 units

Machine learning and sensors are at the core of most modern computing devices and technology. From Amazon Echo to Apple Watch to Google Photos to self-driving cars, making sense of the data coming from powerful but noisy sensors is the key challenge. The aim of the course will be to explore this intersection of sensors and machine learning, understand the inner workings on modern computing technologies, and design the future ones. We will cover data collection, signal processing, data processing, data visualization, feature engineering, machine learning tools, and some prototyping technologies. The course will focus on class discussions, hands-on demonstrations, and tutorials. Students will be evaluated on their class participation, multiple mini projects, and a final team project.

17-437 Web Application Development

Fall and Spring: 12 units

This course will introduce concepts in programming web application servers. We will study the fundamental architectural elements of programming web sites that produce content dynamically. The primary technology introduced will be the Django framework for Python, but we will cover related topics as necessary so that students can build significant applications. Such topics include: HTTP, HTML, CSS, Javascript, JSON, Design Patterns, Relational and Non-relational Databases, Object-Relation Mapping tools, Security, Web Services, Cloud Deployment, Internationalization, and Scalability and Performance Issues. Students must be comfortable programming in Python to register for this course. Students must provide their own computer hardware for this course. Please visit the Course URL for more information about the course.

Prerequisites: 18-613 or 15-513 or 18-213 or 14-513 or 17-214 or 15-214 or 17-514 or 15-213

Course Website: <https://www.cmu-webapps.org/static/index/syllabus.pdf>

17-442 Software Management Theory

Spring: 6 units

This course will look at software development from an organizational perspective and its designed for students who want to understand the relationship between business context, software development processes, knowledge creation, culture and organizational structure with the purpose of becoming change agents or manage the software development function at the department, business unit level or above. The course will also highlight the need to follow good work principles in order to avoid ethical failures as evidenced by recent affairs

17-443 Quality Management

Spring: 6 units

Managing software quality is a critical part of all software projects. Software engineers must consider quality during every phase of a project from inception to delivery and beyond. This class will introduce students to the managerial challenges of developing high quality software systems. The key learning objectives of this course include: 1. Define a quality management process in the context of a software project. 2. Understand the costs associated with achieving quality goals and not achieving them 3. Understand the tradeoffs required to implement quality assurance techniques. 4. Gain experience using collected quality metrics to inform project-level decisions.

Prerequisite: 17-323 Min. grade B

17-445 Machine Learning in Production

Fall and Spring: 12 units

The course takes a software engineering perspective on building software systems with a significant machine learning or AI component. It discusses how to take an idea and a model developed by a data scientist (e.g., scripts and Jupyter notebook) and deploy it as part of scalable and maintainable system (e.g., mobile apps, web applications, IoT devices). Rather than focusing on modeling and learning itself, this course assumes a working relationship with a data scientist and focuses on issues of design, implementation, operation, and assurance and how those interact with the data scientist's modeling. This course is aimed at software engineers who want to understand the specific challenges of working with AI components and at data scientists who want to understand the challenges of getting a prototype model into production; it facilitates communication and collaboration between both roles.

Course Website: <https://ckaestne.github.io/seai/>

17-446 DevOps and Continuous Integration

Spring: 6 units

TBD

Prerequisite: 17-336 Min. grade B

17-450 Crafting Software

Fall and Spring: 12 units

Do you use programming to solve problems in your field of study? Do you know enough to be dangerous, but wish you could be proud of your code? This course aims to provide students with sufficient knowledge and skills to use programming as part of their work. In this class, you will learn how to identify and find problems in your code. You will learn to read, parse, organize, and transform data. We will teach you to write code collaboratively and refine your programs so others can use them. The course will be a mixture of lecture and guided exercise with a recitation focused on hands on instruction. In this course, students are expected to have been exposed to some basic programming concepts, such as variables, if-statements, loops, and arrays. However, students are not expected to have extensive programming experience. This course is not appropriate for students that have completed more than two courses involving programming. We expect students in this class to have diverse backgrounds and experience. Some students will be self-taught, while others will have taken a programming course such as 02-201, 15-110, 95-898, or the library's Software Carpentry workshop. If you have questions about your background and the fit for this class, please don't hesitate to reach out to the instructors.

17-480 API Design and Implementation

Fall and Spring: 12 units

This class focuses on the design of programming interfaces, the APIs, within larger real-world software and ecosystems. We discuss the history and importance of APIs, and the principles behind designing good APIs. This includes study of specific examples of APIs, both good and bad, for inspiration and precaution. Students gain experience with the major steps of API design: gathering requirements, documenting, testing, implementing, refining, evolving, and reimplementing APIs. The principles taught are largely language-independent, though most examples are in Java or C. Students may be able to do assignments in other languages, within reason.

Prerequisites: 15-213 or 15-214 or 17-214

17-514 Principles of Software Construction: Objects, Design, and Concurrency

Fall and Spring: 12 units

Software engineers today are less likely to design data structures and algorithms from scratch and more likely to build systems from library and framework components. In this course, students engage with concepts related to the construction of software systems at scale, building on their understanding of the basic building blocks of data structures, algorithms, and program and computer structures. The course covers technical topics in four areas: (1) concepts of design for complex systems, (2) object-oriented programming, (3) static and dynamic analysis for programs, and (4) concurrency. At the conclusion of this course, students will have substantial experience building medium-sized software systems in Java or JavaScript.

Prerequisites: (15-121 Min. grade C or 15-122 Min. grade C) and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C)

Course Website: <https://www.cs.cmu.edu/~ckaestne/17214/f2021/>

17-536 Pervasive and Ubiquitous Computing

Intermittent: 12 units

Note: Previously offered as 08530. The aim of the class will be to explore the area of Ubiquitous Computing (ubicomputing) and allow students to work on a variety of small technology projects. Students will be exposed to the basics of building ubicomp systems, emerging new research topics, and advanced prototyping techniques. This course will focus more on class discussions and hands on demonstrations, while formal lectures will be conducted only as needed. Students will be evaluated on their class participation, reading summaries, and mini projects.

17-537 Artificial Intelligence Methods for Social Good

Spring: 9 units

Optimization: mathematical programming, robust optimization, influence maximization Game Theory and Mechanism Design: security games, human behavior modeling, auction and market equilibrium, citizen science Machine Learning: classification, clustering, probabilistic graphical models, deep learning Sequential Decision Making: Markov Decision Processes (MDPs), partially observable MDPs, online planning, reinforcement learning In addition to providing a deep understanding of these methods, the course will introduce which societal challenges they can tackle and how, in the areas of (i) healthcare, (ii) social welfare, (iii) security and privacy, (iv) environmental sustainability. The course will also cover special topics such as AI and Ethics and AI and Humans. The course content is designed to not have too much overlap with other AI courses offered at CMU. Although the course is listed within SCS, it should be of interest to students in several other departments, including ECE, EPP and SDS. The students in this 9-unit course are expected to have taken at least three mathematics courses covering linear algebra, calculus, and probability. The students will work in groups on a systematic literature review or a project exploring the possibility of applying existing AI tools to a societal problem, with a survey paper or technical report and presentation delivered at the end of the semester.

17-562 Law of Computer Technology

Fall: 9 units

A survey of how legislatures and courts cope with rapidly advancing computer technologies and how scientific information is presented to, and evaluated by, civil authorities. The course is also an introduction to the legal process generally and the interaction between the legal system and technology organizations. Topics include: patents, copyrights in a networked world, law of the Internet, free speech, data security, technology regulation, international law, and trans-border crime. Open to juniors, seniors and graduate students in any school. Open to sophomores by permission of the instructor. Prerequisites: none.

17-599 Advanced Topics in Machine Learning and Game Theory

Fall: 12 units

This course is designed to be a graduate-level course covering the topics at the intersection of machine learning and game theory. Recent years have witnessed significant advances in machine learning and their successes in detection, prediction, and decision-making problems. However, in many application domains, ranging from auction and ads bidding, to entertainment games such as Go and Poker, to autonomous driving and traffic routing, to the intelligent warehouse, to home assistants and the Internet of Things, there is more than one agent interacting with each other. Game theory provides a framework for analyzing the strategic interaction between multiple agents and can complement machine learning when dealing with challenges in these domains. Therefore, in the course, we will introduce how to integrate machine learning and game theory to tackle challenges in multi-agent systems. The course will multiple topics as listed below

Course Website: <https://feifang.info/advanced-topics-in-machine-learning-and-game-theory-fall-2021/>

17-612 Business and Marketing Strategy

Fall: 6 units

This course prepares technically minded students to understand and use essential business concepts in their careers. With this competency, students will be able to make use of, contribute to, and influence the business and marketing decisions that affect engineering and technology decisions, quality, and performance. Students will be better equipped to make business arguments for supporting their product, technology and engineering ideas in their future, too. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. Each student works on a course-long project where they'll conceive and plan a new technology product idea for an existing company. They'll make product, technological, pricing, marketing, and sales decisions to achieve success and are in support of the company's strategy and business decisions. Their work will culminate in building a compelling business case, with financial projections, to persuade the company executives to invest in the product idea.

Course Website: <https://mse.isri.cmu.edu/>

17-619 Introduction to Real-Time Software and Systems

Intermittent: 12 units

Introduction to Real-Time Software and Systems presents an overview of time as it relates engineering complex systems. Any system that responds at the pace of relevant events has real-time constraints whether the timescale is short, like the flight controls for an aircraft, or longer, like the flight reservation system for an airline. Fundamental concepts, terminology, and issues of real-time systems are introduced in this course. The focus is on software solutions to real-time problems-solutions that must be both correct and timely. Software development is examined with emphasis on real-time issues during each phase of the software lifecycle. Real-time requirements analysis, architecting real-time systems, designing and modeling system timing, and implementation and testing strategies are studied. Modeling techniques using UML 2.0 are applied. Particular emphasis is placed on real-time scheduling to achieve desired timing, reliability, and robustness. Languages and operating systems for real-time computing, and real-time problems in concurrent and distributed systems are explored. This course provides a comprehensive view of real-time systems with theory, techniques and methods for the practitioner. After successfully completing this course, the student will be able to identify constraints and understand real-time issues in system development, and propose approaches to typical real-time problems. The aim of this course is to motivate and prepare students to pursue more in-depth study of specific problems in real-time computing and systems development. REQUIREMENT: Proficiency with a high-level programming language such as C or Ada and basic concepts of computing systems. Familiarity with software engineering concepts and system development lifecycle.

17-621 Computer Simulation of Complex Socio-Technical Systems

Intermittent: 12 units

How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: <http://www.casos.cs.cmu.edu/courses/>

17-624 Advanced Formal Methods

Fall: 6 units

This course builds on the introductory Models class to cover more advanced techniques for modeling and reasoning about complex software systems. Concepts introduced in this course include abstraction and refinement, declarative specifications, advanced temporal logics, and probabilistic modeling. The course will also explore applications of modeling and automated reasoning techniques in various domains, such as security, distributed computing, and cyber-physical systems. After completing this course, students will: 1. Understand how to specify and reason about operations over complex system structures. 2. Understand relationships between software artifacts at different levels of abstraction; 3. Be able to model and reason about systems with uncertainty and stochastic behaviors; and 4. Understand potential applications of modeling techniques to practical software engineering problems. Prerequisites: Completion of Mini 1: Models of Software Systems. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not a software engineering master's student, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken a course with similar materials as in Mini 1, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

Prerequisite: 17-614 Min. grade B

17-626 Requirements for Information Systems

Fall: 6 units

Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements using scenarios, use cases and mockups.

17-627 Requirements for Embedded Systems

Fall: 6 units

Software engineering requires understanding the problem, before identifying solutions. In this course, students study ways to elicit and analyze problem statements for real-time systems along multiple dimensions, including concurrency, dependability and safety.

Prerequisite: 17-614 Min. grade B

17-634 Applied Machine Learning

Spring: 6 units

Autonomous and intelligent systems increasingly rely on automated decision making based on statistical models used for classification or prediction. The practical application of machine learning requires understanding the underlying theoretical assumptions behind a wide variety of statistical models, how to analyze the performance of such models, and how to integrate models into data processing pipelines. This course introduces students to supervised and unsupervised machine learning in the context of software engineering, including the analysis of natural language in bug reports and mobile app reviews. Techniques covered include latent Dirichlet allocation, TF/IDF, naive Bayes, linear regression, decision trees, and random forests.

17-640 IoT, Big Data, and ML: A Hands-on Approach

Intermittent: 12 units

This course is designed to teach IoT concepts, big data, and machine learning techniques using a hands-on approach. An IoT system simulating an order fulfillment process is central to the hands-on learning of the concepts and techniques. Students will work in 4-5 person teams to enable the system and implement the requirements. In doing so, they will incorporate sound design principles of software engineering acquired in lectures. Students will capture the data generated during the execution of the system as it fulfills orders that are received from a front-end system developed by the students. Students will be expected to prepare, process, and model the data for statistical analysis applying techniques taught in class. They will then visualize, analyze and interpret the results, and implement improvements to obtain a 360-degree experience of a business application using the automated system. This course will provide insight into the ways in which business enterprises think about leveraging technology and software in the management of their production operations. The course prepares students for professional opportunities requiring such skills allowing them to identify use cases that facilitate innovation and promote competitiveness.

17-644 Applied Deep Learning

Spring: 6 units

Deep neural networks have made in-roads in virtually every industry, propelled by exponential increases in compute power and fundamental progress in modeling. Knowledge of these models is fast becoming a key asset for software engineers, as current systems are quickly starting to include many neural components, and the practice of software engineering itself is starting to benefit from neural program assistance (incl. automated bug finding, translation between programming languages). This course equips the next generation of software engineers with knowledge of neural models, the software engineering challenges involved in using these, and hands-on experience with their applications. It teaches both a rich vocabulary of general, essential concepts (including architectures), and recent work on applications of these models, aimed primarily at applications for and in software engineering itself. The course includes a group project aimed at constructing a neural solution for an existing application that will be used to teach the various stages (and their pitfalls) of building and deploying deep learners.

17-651 Models of Software Systems

Fall: 12 units

Scientific foundations for software engineering depend on the use of precise, abstract models for describing and reasoning about properties of software systems. This course considers a variety of standard models for representing sequential and concurrent systems, such as state machines, algebras, and traces. It shows how different logics can be used to specify properties of systems, such as functional correctness, deadlock freedom, and internal consistency. Concepts such as compositionality, abstraction, invariants, non-determinism, and inductive definitions are recurrent themes throughout the course. After completing this course, students will: 1. Understand the strengths and weaknesses of certain models and logics including state machines, algebraic and process models, and temporal logic; 2. Be able to select and describe appropriate abstract formal models for certain classes of systems, describe abstraction relations between different levels of description, and reason about the correctness of refinements; 3. Be able to prove elementary properties about systems described by the models introduced in the course; and 4. Understand some of the strengths and weakness of formal automated reasoning tools. Prerequisites: Undergraduate discrete math including first-order logic, sets, functions, relations, and simple proof techniques such as induction. Sections D, PP and G are NOT available for on-campus students. Admission to the class is by approval from the instructor: If you are not MSE/MSIT-SE/MITS, send email to garlan@cs.cmu.edu for permission to enroll. The email should briefly describe your background, whether you have taken an undergraduate discrete math course, and why you would like to take the course. The course must be taken for a letter grade (not pass/fail). This is a graduate level course.

17-654 Analysis of Software Artifacts

Spring: 12 units

Analysis is the systematic examination of an artifact to determine its properties. This course will focus on analysis of software artifacts and #8212;primarily code, but also including analysis of designs, architectures, and test suites. We will focus on functional properties, but also cover non-functional properties like performance and security. In order to illustrate core analysis concepts in some depth, the course will center on static program analysis; however, the course will also include a breadth of techniques such as testing, model checking, theorem proving, dynamic analysis, and type systems. The course will balance theoretical discussions with lab exercises in which students will apply the ideas they are learning to real artifacts. After completing this course, students will: * know what kinds of analyses are available and how to use them * understand their scope and power, when they can be applied and what conclusions can be drawn from their results * have a grasp of fundamental notions sufficient to evaluate new kinds of analysis when they are developed * have some experience selecting and writing analyses for a real piece of software, applying them and interpreting the results Ph.D. students taking the 17-754 version of the course will gain a broad overview of the analysis research literature and in-depth knowledge of a particular sub-area through a course project. Requirement: A recent discrete math course and programming experience. Strongly Recommended: Models of SW Development course (17-651) before taking this course. This course is for letter grade only (no pass/fail grades). This is a graduate course. Only undergrad SE minors may take this course with the instructor's permission. Please note: Students outside of the software engineering department may take this course but students of the MSE programs will have first priority.

17-663 Programming Language Pragmatics

Fall: 12 units

This course provides a broad and pragmatic foundation in the most basic tool of the programmer: programming languages. It starts with the fundamentals of syntax, parsing, and binding, the core structural concepts in programming languages. The course will then cover program semantics and type systems, and students will learn to relate them with a type soundness theorem. Finally, a coverage of intermediate optimization and code generation offers the opportunity to discuss both producing efficient code and reasoning about the correctness of program transformations. Assignments involve a combination of tool-assisted formal reasoning and proofs about programming languages, and implementing these language constructs in a compiler. This course fulfills the Logic and amp; Languages constrained elective of the B.S. in Computer Science. Students with substantial math and programming experience who have not satisfied the specific prerequisites can contact the instructor for permission to enroll. Prerequisites: 15-251 Min. grade C and (15-150 Min. grade C or 21-228 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~aldrich/courses/17-363/>**17-670 Virtual Machines and Managed Runtimes**

Fall: 12 units

Traditional compiler and programming language courses focus on language implementations that generate code statically (offline) for a target machine. Yet in today's landscape, many programming languages run on virtual machines where either a virtual instruction set architecture (bytecode) or the source code of the program is translated (and optimized) dynamically for an underlying machine. Such languages come with additional challenges beyond traditional compilation as taught in courses, including efficient representation of high-level language constructs and automatic memory management in the form of garbage collection. Together, the components of the virtual machine and services form what is known as a managed runtime system. This course focuses on implementation techniques for managed runtime systems. Students will learn the basics of virtual machine implementation and build working prototypes to run actual programs. Prior knowledge of compilers and some familiarity with programming language implementation is required.

Prerequisites: 15-611 or 15-411

17-685 Dynamic Network Analysis

Spring: 12 units

Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays a role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-691 Machine Learning in Practice**

Spring: 6 units

As Machine Learning and Artificial Intelligence methods have become common place in both academic and industry environments the majority of resources have focused on methods and techniques for applications. However, there are many considerations that must be addressed when deploying such techniques into practice (or production). The purpose of this course is to cover topics relevant to building a machine learning systems deployed into operations. Such systems have technical requirements including data management, model development, and deployment. However, business/organizational impacts must also be considered. Machine learning systems can be expensive to produce and operate. Students will learn about trade-offs in design, implementation, and expected value. After completing this course, students will: 1. Have the ability to deploy produces with machine learning and AI components; 2. Understand how to implement data pipelines and data engineering systems; 3. Calculate the approximate value provided by a machine learning system to an organization; 4. Understand how to continually assess the value and quality of a deployed machine learning system. Prerequisites: understanding of basic machine learning concepts (i.e. supervised/unsupervised learning). This is a graduate level course.

Prerequisite: 17-634 Min. grade B

17-692 Product Management Essentials

Spring: 6 units

This course prepares technically minded students to understand and use the essential product management concepts and practices at the earliest stage of every new product innovation idea. With this understanding and skills, students will be able to identify and define a worthwhile customer problem to solve, conceive of an innovative, differentiated product solution, design and quantify a compelling customer value proposition and set a strategy for continued innovation and growth. This 6-unit course emphasizes learning-by-doing to achieve the learning objectives. You will work on a hands-on, course-long project focused on a problem space selected by the student and approved by the instructor for course fit. PRIORITY is given to students in the Master of Software Engineering (MSE), MS in Engineering and amp; Technology Innovation Management and Master of Information Systems Management degree programs. Make sure you register for the section according to the criteria listed in "Extra Time Commitments."

17-702 Current Topics in Privacy Seminar

Fall and Spring: 3 units

In this seminar course students will discuss recent papers and current public policy issues related to privacy. Privacy professionals from industry, government, and non-profits will deliver several guest lectures each semester.

17-712 Fantastic Bugs and How to Find Them

Spring: 12 units

This advanced course studies the nature of software bugs and security vulnerabilities arising in complex application domains and surveys specialized program analysis + automated testing techniques for identifying such issues proactively. The course will take a tour of various domains such as mobile systems, databases, web browsers, distributed and networked systems, autonomous vehicles, and smart contracts. For each domain, the class will review case studies of high-impact software bugs that have manifested in production and will then discuss state-of-the-art research techniques that aim to uncover such bugs automatically. Apart from the literature review, students will engage significantly with software system design and engineering via hands-on assignments and a semester-long project involving real-world applications and analysis tools for one or more domains. Students completing this course will be able to (a) identify practical challenges of applying well-known program analysis and testing techniques to complex application domains, (b) formulate and leverage domain-specific assumptions for making analysis techniques tractable in a specialized setting, and (c) build practical tools for improving software quality in large-scale systems. The course assumes that students have some background in reasoning about software quality, system security, and/or working with program representations. The course builds upon mathematical principles introduced in foundational classes on program analysis, verification, or compiler design, as well as system design principles encountered in introductory security or software engineering courses. Please check the course website for classes that qualify as sufficient pre-requisites, or contact the instructor to discuss your background.

Course Website: <https://cmu-fantastic-bugs.github.io/>**17-731 Foundations of Privacy**

Fall: 12 units

Privacy is a significant concern in modern society. Individuals share personal information with many different organizations - healthcare, financial and educational institutions, the census bureau, Web services providers and online social networks - often in electronic form. Privacy violations occur when such personal information is inappropriately collected, shared or used. We will study privacy in a few settings where rigorous definitions and enforcement mechanisms are being developed - statistical disclosure limitation (as may be used by the census bureau in releasing statistics), semantics and logical specification of privacy policies that constrain information flow and use (e.g., by privacy regulations such as the HIPAA Privacy Rule and the Gramm-Leach-Bliley Act), principled audit and accountability mechanisms for enforcing privacy policies, anonymous communication protocols - and other settings in which privacy concerns have prompted much research, such as in social networks, location privacy and Web privacy (in particular, online tracking and amp; targeted advertising).

17-733 Privacy Policy, Law, and Technology

Fall: 12 units

NOTE: Previously offered as 08-733. This course focuses on policy issues related to privacy from the perspectives of governments, organizations, and individuals. We will begin with a historical and philosophical study of privacy and then explore recent public policy issues. We will examine the privacy protections provided by laws and regulations, as well as the way technology can be used to protect privacy. We will emphasize technology-related privacy concerns and mitigation, for example: social networks, smartphones, behavioral advertising (and tools to prevent targeted advertising and tracking), anonymous communication systems, big data, and drones. This is part of a series of courses offered as part of the MSIT-Privacy Engineering masters program. These courses may be taken in any order or simultaneously. Foundations of Privacy (Fall semester) offers more in-depth coverage of technologies and algorithms used to reason about and protect privacy. Engineering Privacy in Software (Spring semester) focuses on the methods and tools needed to design systems for privacy. This course is intended primarily for graduate students and advanced undergraduate students with some technical background. Programming skills are not required. 8-733, 19-608, and 95-818 are 12-unit courses for PhD students. Students enrolled under these course numbers will have extra assignments and will be expected to do a project suitable for publication. 8-533 is a 9-unit course for undergraduate students. Masters students may register for any of the course numbers permitted by their program. This course will include a lot of reading, writing, and class discussion. Students will be able to tailor their assignments to their skills and interests. However, all students will be expected to do some writing and some technical work.

17-735 Engineering Privacy in Software

Spring: 12 units

Privacy harms that involve personal data can often be traced back to software design failures, which can be prevented through sound engineering practices. In this course, students will learn how to identify privacy threats due to surveillance activities that enhance modern information systems, including location tracking, behavioral profiling, recommender systems, and social networking. Students will learn to analyze systems to identify the core operating principles and technical means that introduce privacy threats, and they will learn to evaluate and mitigate privacy risks to individuals by investigating system design alternatives. Strategies to mitigating privacy risk will be based on emerging standards and reliable privacy preference data. Students will have the opportunity to study web-, mobile- and cyber-physical systems across a range of domains, including advertising, healthcare, law enforcement and social networking. In addition, students will know how, and when, to interface with relevant stakeholders, including legal, marketing and other developers in order to align software design with privacy policy and law.

17-756 Computational Social Science Research Design and Data Analytics

Spring: 12 units

This course surveys how digital trace data of human activity online, combined with careful research design and data analytics, have led to surprising discoveries and development of novel theoretical explanations in the field of computational social science (CSS). The course has three aims. (a) It is intended to stimulate new ways of formulating research questions on pressing/emerging societal issues of interest (e.g., political polarization, gender representation in open-source software development, decentralized governance based on blockchain technology) given the possibilities afforded by a wide array of digital trace data (e.g., social media, open-source software collaboration, cryptocurrency transactions, satellite imagery). This course will (b) discuss exemplary works in CSS that made novel discoveries or made theoretical and/or methodological breakthroughs and (c) cover practical considerations that commonly arise in a CSS research project cycle. These issues may include, but are not limited to, data collection (sampling methods and bias), repurposing existing datasets that were collected in a different research context, constructing metrics based on theoretical insights, analytic approaches adequate for a given research question (statistical modeling, network analysis, online experiments, simulation-based theory development), big data processing and analytic tools (distributed data processing frameworks, visualization), ethical considerations, and data sharing. In the end, this course will help participants develop "good taste" for theoretically insightful, methodologically creative, and well thought out research, while learning to identify potential pitfalls that could arise in their own research.

17-801 Dynamic Network Analysis

Spring: 12 units

Who knows who? Who knows what? Who is influential? What is the social network, the knowledge network, the activity network? How do ideas, products and amp; diseases propagate through groups and impact these networks? Does social media change the way these networks operate? Questions such as these and amp; millions of others require a network perspective and an understanding of how ties among people, ideas, things, and amp; locations connect, constrain and amp; enable activity. In the past decade there has been an explosion of interest in network science moving from the work on social networks and graph theory to statistical and computer simulation models. Network analysis, like statistics, now plays a role in most empirical fields. Network science is a broad and multi-disciplinary field. In this class, students will gain an appreciation of the history of the field, the difference between social networks and social media, the difference graph-based metrics for network analysis and graphical models, the use of traditional and high dimensional network models, and the advances in this field. Applications and issues discussed will include: social media analytics, semantic networks, task networks, organizational design and teams, machine learning and network analysis, generative models, terrorism and crime, health, and fake news. Methods for network data collection, analysis, visualization, and interpretation are covered. Students produce original research in which network data is analyzed using the methods covered in the class.

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-821 Computer Simulation of Complex Socio-Technical Systems**

Spring: 12 units

How likely is an intervention like social distancing to save lives? Will a law legislating sanctions against social media platforms that spread disinformation stop the spread? We live and work in complex adaptive and evolving socio-technical systems where questions such as these arise constantly. Questions such as these are often only addressable through computational modeling, i.e., through simulation. Simulation models are a critical method for understanding how to adaptation and learning will change the status-quo. Computational modeling can be used to help analyze, reason about, predict the behavior of, and possibly control complex human systems of "networked" agents. Using simulation it is possible to advance theory, test policies before enacting them, and think through non-linear social effects.

Course Website: <http://www.casos.cs.cmu.edu/courses/>**17-880 Algorithms for Private Data Analysis**

Spring: 12 units

We study the following question in this course: How do we perform useful analysis on a data set that contains sensitive information about individuals without compromising the privacy of those individuals? To study this question, we will introduce differential privacy, a framework of designing data analysis algorithms with strong, meaningful, and mathematically provable privacy guarantees. We will survey a set of algorithmic tools that allow us to privately perform a wide range of statistical analyses. Of course, privacy does not come for free, and we will also study some of the fundamental limitations imposed by the requirement of differential privacy. Through the discussion of these results, we will also demonstrate some of the most novel and surprising connections between differential privacy and other areas of theoretical computer science, including machine learning theory, cryptography, convex geometry, and game theory.

Language Technologies Institute Courses**11-291 Applied Computational Intelligence Lab**

Intermittent: 9 units

What would an "intelligent" picture on the wall do? What if it could see and hear you? What should it say if it could talk? What if your pantry, wardrobe or medicine cabinet could sense, think and act? What should they do and say? What should your cell phone be saying to you? These are not whimsical or theoretical questions...they inevitably arise as ordinary everyday objects around us acquire the ability to sense changes in their environment, think about their implications, and act in pursuit of their goals. These objects are connected to the web and become conduits for services, erasing the distinction between products and services. The ability to invent and build smart products/services is becoming a key skill in the new technology-driven services economy. The focus of the course will be on building "ordinary" objects that can sense, think and act in the real world and on exploring the implications of these capabilities. Students will select their own project and by the end of the semester will create a working prototype that will be exhibited in a public place. Prizes will be offered for the most creative projects. In the course of their projects, students will learn how to use state-of-the-art tools for: Object detection using video cameras, microphones and other sensors Movement and gesture detection Speech recognition and generation Reasoning and planning: While the course organizers have many ideas for specific projects, students will be encouraged to design their own projects. Students are expected to work in small groups on their own time and receive faculty advice as needed. There will be weekly meetings of the whole class.

Prerequisites: 15-122 Min. grade C and 21-127 Min. grade C

11-324 Human Language for Artificial Intelligence

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-344 Machine Learning in Practice

Fall and Spring: 12 units

Machine Learning is concerned with computer programs that enable the behavior of a computer to be learned from examples or experience rather than dictated through rules written by hand. It has practical value in many application areas of computer science such as on-line communities and digital libraries. This class is meant to teach the practical side of machine learning for applications, such as mining newsgroup data or building adaptive user interfaces. The emphasis will be on learning the process of applying machine learning effectively to a variety of problems rather than emphasizing an understanding of the theory behind what makes machine learning work. This course does not assume any prior exposure to machine learning theory or practice. In the first 2/3 of the course, we will cover a wide range of learning algorithms that can be applied to a variety of problems. In particular, we will cover topics such as decision trees, rule based classification, support vector machines, Bayesian networks, and clustering. In the final third of the class, we will go into more depth on one application area, namely the application of machine learning to problems involving text processing, such as information retrieval or text categorization.

11-345 Undergrad Independent Study

All Semesters

No course description provided.

11-364 An Introduction to Knowledge-Based Deep Learning and Socratic Coaches

Spring: 12 units

The subject of this course will be deep learning, one of the most dynamic and exciting emerging areas of computer science. Deep learning deals with and is conquering the problems resulting from the enormous quantity of data that now surrounds us. Furthermore, the course will explore knowledge-based deep learning, a new methodology invented by the instructor that offers many potential advantages over conventional deep learning. This is a learn-by-doing, team-project based course, which will be divided into four phases. In phase one, each student will read and present a number of papers describing state-of-the-art deep learning systems and successful applications. In phase two, each team will implement the system described in one of the papers. In phase three, each team will scale that implementation to one of the large benchmark datasets. In phase four, each team will do a special research project implementing a knowledge-based deep learning system based on pending patent applications of Professor Baker. As a potential follow-on for successful projects, students may participate in a summer course on entrepreneurial applications of deep learning or work as interns in a bootstrap startup based on the knowledge-based deep learning projects. Prerequisite: Strong quantitative aptitude, programming skill, ability to quickly absorb new ideas, teamwork skills.

11-390 LTI Minor Project - Juniors

All Semesters: 12 units

No course description provided.

11-411 Natural Language Processing

Intermittent: 12 units

This course is about a variety of ways to represent human languages (like English and Chinese) as computational systems, and how to exploit those representations to write programs that do neat stuff with text and speech data, like translation, summarization, extracting information, question answering, natural interfaces to databases, and conversational agents. This field is called Natural Language Processing or Computational Linguistics, and it is extremely multidisciplinary. This course will therefore include some ideas central to Machine Learning and to Linguistics. We'll cover computational treatments of words, sounds, sentences, meanings, and conversations. We'll see how probabilities and real-world text data can help. We'll see how different levels interact in state-of-the-art approaches to applications like translation and information extraction. From a software engineering perspective, there will be an emphasis on rapid prototyping, a useful skill in many other areas of Computer Science. Prerequisite: 15-122

11-422 Grammar Formalisms

Spring: 12 units

TBA

11-423 ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang.

Spring: 12 units

Students will work individually or in small groups to create artificial human(oid) languages for fictional human cultures or SciFi worlds. Students will implement language technologies for their languages. In the course of creating the languages, students will learn about the building blocks of human language such as phones, phonemes, morphemes, and morpho-syntactic constructions including their semantics and pragmatics. Class instruction will focus specifically on variation among human languages so that the students can make conlangs that are not just naively English-like. We will also touch on philosophical issues in philosophy of language and on real-world socio-political issues related to language policy. Students will be required to use at least one of the following technologies: language documentation tools that are used for field linguistics and corpus annotation, automatic speech recognition, speech synthesis, morphological analysis, parsing, or machine translation. Learning Objectives: 1. The building blocks (phonemes, morphemes, etc.) of language, how languages are built from them, and how they interact 2. Metalinguistic awareness and knowledge about variation in human language 3. Language, thought, and culture: how does language reflect thought and culture, and vice versa. Why wouldn't Elvish be a good language for Klingons? 4. Language policy in the real world: For students who want to manipulate real languages. 5. Historical linguistics and language change: for students who want to manipulate real languages or make families of related conlangs for fictional worlds. 6. Practical experience with a language technology. <http://tts.speech.cs.cmu.edu/11-823/> Course Website: <http://tts.speech.cs.cmu.edu/11-823/> (<http://tts.speech.cs.cmu.edu/11-823/>)

11-439 Designing Around Patents on Machine Learning and NLP Technology

Spring: 9 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraints, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-441 Machine Learning for Text and Graph-based Mining

Fall and Spring: 9 units

This course provides a comprehensive introduction to the theory and implementation of algorithms for organizing and searching large text collections. The first half of the course studies text search engines for enterprise and Web environments; the open-source Indri search engine is used as a working example. The second half studies text mining techniques such as clustering, categorization, and information extraction. Programming assignments give hands-on experience with document ranking algorithms, categorizing documents into browsing hierarchies, and related topics.

11-442 Search Engines

Fall: 9 units

This course studies the theory, design, and implementation of text-based search engines. The core components include statistical characteristics of text, representation of information needs and documents, several important retrieval models, and experimental evaluation. The course also covers common elements of commercial search engines, for example, integration of diverse search engines into a single search service ("federated search", "vertical search"), personalized search results, diverse search results, and sponsored search. The software architecture components include design and implementation of large-scale, distributed search engines.

Course Website: <http://boston.lti.cs.cmu.edu/classes/11-642/>

11-485 Introduction to Deep Learning

Intermittent: 9 units

Neural networks have increasingly taken over various AI tasks, and currently produce the state of the art in many AI tasks ranging from computer vision and planning for self-driving cars to playing computer games. Basic knowledge of NNs, known currently in the popular literature as "deep learning", familiarity with various formalisms, and knowledge of tools, is now an essential requirement for any researcher or developer in most AI and NLP fields. This course is a broad introduction to the field of neural networks and their "deep" learning formalisms. The course traces some of the development of neural network theory and design through time, leading quickly to a discussion of various network formalisms, including simple feedforward, convolutional, recurrent, and probabilistic formalisms, the rationale behind their development, and challenges behind learning such networks and various proposed solutions. We subsequently cover various extensions and models that enable their application to various tasks such as computer vision, speech recognition, machine translation and playing games. Instruction Unlike prior editions of 11-785, the instruction will primarily be through instructor lectures, and the occasional guest lecture. Evaluation Students will be evaluated based on weekly continuous-evaluation tests, and their performance in assignments and a final course project. There will be six hands-on assignments, requiring both low-level coding and toolkit-based implementation of neural networks, covering basic MLP, convolutional and recurrent formalisms, as well as one or more advanced tasks, in addition to the final project.

Prerequisites: 15-112 and 21-120 and 21-241

11-488 Concepts in Digital Multimedia and Cyber Forensics

Spring: 12 units

This course covers the use of computational methods in crime investigation (forensics) and prevention (intelligence). In almost all areas of forensics and intelligence, computational methods continue to aid, and sometimes entirely replace, human expertise in tracking crime. This is desirable since automation can address the problems associated with scale and global crime linkage through diverse data computational tools can potentially overcome and surpass human capabilities for crime investigation. This course is of a cross-disciplinary nature. It amalgamates knowledge from criminology, forensic sciences, computer science, statistics, signal processing, machine learning, AI, psychology, medicine and many other fields. Students from all departments and schools are welcome to take this course.

Course Website: <https://forensics-ai.github.io/gh-syllabus/>**11-490 LTI Minor Project - Seniors**

All Semesters: 12 units

No course description provided.

11-492 Speech Processing

Spring: 12 units

Speech Processing offers a practical and theoretical understanding of how human speech can be processed by computers. It covers speech recognition, speech synthesis and spoken dialog systems. The course involves practicals where the student will build working speech recognition systems, speech synthesis systems and integrate them to create a speech interface. This work will be based on existing toolkits. Details of algorithms, techniques and limitations of state of the art speech systems will also be presented. This course is designed for students wishing understand how to process real data for real applications, applying statistical and machine learning techniques as well as working with limitations in the technology.

Prerequisite: 15-210

11-546 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units

Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University's Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry's need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with a equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: <https://luimagroup.github.io/appliedlegalanalytics/>**11-590 LTI Minor Project - Advanced**

All Semesters: 12 units

No course description provided.

11-603 Python for Data Science

Summer: 12 units

Students learn the concepts, techniques, skills, and tools needed for developing programs in Python. Core topics include types, variables, functions, iteration, conditionals, data structures, classes, objects, modules, and I/O operations. Students get an introductory experience with several development environments, including Jupyter Notebook, as well as selected software development practices, such as test-driven development, debugging, and style. Course projects include real-life applications on enterprise data and document manipulation, web scraping, and data analysis.

Course Website: <https://canvas.andrew.cmu.edu>**11-624 Human Language for Artificial Intelligence**

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

11-630 MCDS Practicum Internship

Summer

The MCDS Practicum course is used for recording CDS students summer internships for the MCDS Program.

11-639 Designing Around Patents on Machine Learning and NLP Technology

Spring: 12 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students' software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the students' skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithms' performance as possible. In essence, students will view the presence of particular patents as a design constraint, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-646 Applied Legal Analytics & Artificial Intelligence

Spring: 12 units

Technological advances are affecting the legal profession and enable innovation by experts proficient in both law and AI technology. This joint course, co-taught by instructors from the University of Pittsburgh School of Law and Carnegie Mellon University's Language Technologies Institute, provides a hands-on practical introduction to the fields of artificial intelligence and law, machine learning, and natural language processing as they are being applied to support the work of legal professionals, researchers, and administrators, such as extracting semantic information from legal documents and using it to solve legal problems. Meanwhile, LegalTech companies and startups have been tapping into the industry's need to make large-scale document analysis tasks more efficient, and to use predictive analytics for better decision making. This course is intended to bring students of law and technical disciplines together into a collaborative classroom setting to learn about the technologies at the intersection of law and AI through lectures and programming exercises, as well as gain practical experience through collaborative project work. Topics in focus include machine learning and natural language applied to legal data, computational models of legal reasoning, and selected legal issues that relate to AI technologies. Students should come from either a (pre-) law background with a strong interest in gaining practical experience with legal analytics, or from a technical discipline with an equally strong interest in tackling the challenges posed by legal analytics tasks and data.

Course Website: <https://luimagroup.github.io/appliedlegalanalytics/>**11-661 Language and Statistics**

Fall: 12 units

Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: <http://www.cs.cmu.edu/~roni/11661/>**11-667 Large Language Models Methods and Application**

Fall: 12 units

This course provides a broad foundation for understanding, working with, and adapting existing tools and technologies in the area of Large Language Models like BERT, T5, GPT, and others. It begins with a short history of the area of language models and quickly transitions to a broad survey of the area, offering exposure to the gamut of topics including systems, data, data filtering, training objectives, RLHF/instruction tuning, ethics, policy, evaluation, and other human-facing issues. Students will delve into Transformer architectures more broadly and how they work, as well as exploring the reasons why they are better than LSTM-based seq2seq, decoding strategies, etc. Students will learn through readings and hands-on assignments where they will explore techniques for pretraining, attention, prompting, etc. They will then apply these skills in a semester-long course project, making use of locally sourced model instances that offer the opportunity to explore behind the curtain of commercial APIs. Prerequisites: 11-711 or 11-785 or 11-685 or 10-601 or 10-701

11-696 MIIS Capstone Planning Seminar

Spring: 6 units

The MIIS Capstone Planning Seminar prepares students to complete the MIIS Capstone Project in the following semester. Students are organized into teams that will work together to complete the capstone project. They define project goals, requirements, success metrics, and deliverables; and they identify and acquire data, software, and other resources required for successful completion of the project. The planning seminar must be completed in the semester prior to taking the capstone project.

11-697 Introduction to Question Answering

Fall: 12 units

The Introduction to Question Answering course provides a chance for hands-on, in-depth exploration of core algorithmic approaches to question answering (QA) for students who haven't worked on a QA system before.

11-711 Advanced Natural Language Processing

Fall: 12 units

Advanced natural language processing is an introductory graduate-level course on natural language processing aimed at students who are interested in doing cutting-edge research in the field. In it, we describe fundamental tasks in natural language processing such as syntactic, semantic, and discourse analysis, as well as methods to solve these tasks. The course focuses on modern methods using neural networks, and covers the basic modeling and learning algorithms required therefore. The class culminates in a project in which students attempt to reimplement and improve upon a research paper in a topic of their choosing.

11-716 Graduate Seminar on Dialog Processing

All Semesters: 6 units

Dialog systems and processes are becoming an increasingly vital area of interest both in research and in practical applications. The purpose of this course will be to examine, in a structured way, the literature in this area as well as learn about ongoing work. The course will cover traditional approaches to the problem, as exemplified by the work of Grosz and Sidner, as well as more recent work in dialog, discourse and evaluation, including statistical approaches to problems in the field. We will select several papers on a particular topic to read each week. While everyone will do all readings, a presenter will be assigned to overview the paper and lead the discussion. On occasion, a researcher may be invited to present their own work in detail and discuss it with the group. A student or researcher taking part in the seminar will come away with a solid knowledge of classic work on dialog, as well as familiarity with ongoing trends.

11-721 Grammars and Lexicons

All Semesters: 12 units

Grammars and Lexicons is an introductory graduate course on linguistic data analysis and theory, focusing on methodologies that are suitable for computational implementations. The course covers major syntactic and morphological phenomena in a variety of languages. The emphasis will be on examining both the diversity of linguistic structures and the constraints on variation across languages. Students will be expected to develop and defend analyses of data, capturing linguistic generalizations and making correct predictions within and across languages. The goal is for students to become familiar with the range of phenomena that occur in human languages so that they can generalize the insights into the design of computational systems. The theoretical framework for syntactic and lexical analysis will be Lexical Functional Grammar. Grades will be based on problem sets and take-home exams.

11-722 Grammar Formalisms

Intermittent: 12 units

The goal of this course is to familiarize students with grammar formalisms that are commonly used for research in computational linguistics, language technologies, and linguistics. We hope to have students from a variety of disciplines (linguistics, computer science, psychology, modern languages, philosophy) in order to cover a broad perspective in class discussions. Comparison of formalisms will lead to a deeper understanding of human language and natural language processing algorithms. The formalisms will include: Head Driven Phrase Structure Grammar, Lexical Functional Grammar, Tree Adjoining Grammar and Categorical Grammar. If time permits, we will cover Penn Treebank, dependency grammar, and Construction Grammar. We will cover the treatment of basic syntactic and semantic phenomena in each formalism, and will also discuss algorithms for parsing and generating sentences for each formalism. If time permits, we may discuss formal language theory and generative capacity. The course is taught jointly by the following faculty of the Language Technologies Institute: Alan Black Alon Lavie Lori Levin (main coordinator)

11-724 Human Language for Artificial Intelligence

Fall: 12 units

An enduring aspect of the quest to build intelligent machines is the challenge of human language. This course introduces students with a background in computer science and a research interest in artificial intelligence fields to the structure of natural language, from sound to society. It covers phonetics (the physical aspects of speech), phonology (the sound-structure of language), morphology (the structure of words), morphosyntax (the use of word and phrase structure to encode meaning), syntactic formalisms (using finite sets of production rules to characterize infinite configurations of structure), discourse analysis and pragmatics (language in discourse and communicative context), and sociolinguistics (language in social context and social meaning). Evaluation is based on seven homework assignments, a midterm examination, and a final examination.

Course Website: <http://www.lti.cs.cmu.edu/Courses/11-724-desc.htm>**11-731 Machine Translation and Sequence-to-Sequence Models**

Spring: 12 units

Instructors: Graham Neubig. Prerequisites: This course has no official pre-requisites, although 11-711 "Algorithms for NLP" or 10-701 "Machine Learning" would be helpful. Course Description: Machine Translation and Sequence-to-Sequence Models is an introductory graduate-level course surveying the primary approaches and methods for developing systems to translate between human languages, or other sequential data. The main objective of the course is to obtain basic understanding and implementation skills for modern methods for MT and sequence transduction, including how to design models, how to learn the model parameters, how to search for the best output, and how to create training data. The course will focus on machine translation, but also briefly cover tasks such as dialog response generation, image caption generation, and others.

11-737 Multilingual Natural Language Processing.

Fall: 12 units

11737 Multilingual Natural Language Processing is an advanced graduate-level course on natural language processing techniques applicable to many languages. Students who take this course should be able to develop linguistically motivated solutions to core and applied NLP tasks for any language. This includes understanding and mitigating the difficulties posed by lack of data in low-resourced languages or language varieties, and the necessity to model particular properties of the language of interest such as complex morphology or syntax. The course will introduce modeling solutions to these issues such as multilingual or cross-lingual methods, linguistically informed NLP models, and methods for effectively bootstrapping systems with limited data or human intervention. The project work will involve building an end-to-end NLP pipeline in a language you don't know.

Course Website: <https://www.cs.cmu.edu/~leili/course/11737mnlp23fa/>**11-739 Designing Around Patents on Machine Learning and NLP Technology**

Spring: 12 units

This course uses Machine Learning and Natural Language Processing as vehicles to teach principles in designing software to avoid patents. After introducing students to the basics of patents, we investigate how to use students' software skills to design around patents that is, create new technology that avoids a patent while maintaining some, or even all, of the performance and value of the patented technology. Designing around a patent can be viewed as a puzzle that requires technical skill, understanding the business value of technology, knowledge of patents, and creativity. Students will also be able to help design patents that cannot be easily designed-around. Not only does this add a valuable new dimension to the student's skill set, the course material is organized as a vehicle for refining knowledge of ML and NLP techniques. We will practice by designing around patents on well-known ML and NLP algorithms. Students study the basic algorithm, learn the patents that cover those algorithms, and then experiment with software modifications that avoid the patent while preserving as much of the algorithm's performance as possible. In essence, students will view the presence of particular patents as a design constraint, akin to designing for limited memory, bandwidth, or processor speed. Students must have already taken courses in Natural Language Processing (e.g., 11-411) and Machine Learning (e.g., 10-315). Law of Computer Technology 17-562, 17-662, 17-762 or Patents, Licensing, and Innovation 19-473, 19-673 are helpful but not required.

11-741 Machine Learning for Text and Graph-based Mining

Fall and Spring: 12 units

This course studies the theory, design, and implementation of text-based information systems. The Information Retrieval core components of the course include statistical characteristics of text, representation of information needs and documents, several important retrieval models (Boolean, vector space, probabilistic, inference net, language modeling), clustering algorithms, automatic text categorization, and experimental evaluation. The software architecture components include design and implementation of high-capacity text retrieval and text filtering systems. A variety of current research topics are also covered, including cross-lingual retrieval, document summarization, machine learning, topic detection and tracking, and multi-media retrieval. Prerequisites: Programming and data-structures at the level of 15-212 or higher. Algorithms comparable to the undergraduate CS algorithms course (15-451) or higher. Basic linear algebra (21-241 or 21-341). Basic statistics (36-202) or higher.

11-747 Neural Networks for NLP

All Semesters: 12 units

Neural networks provide powerful new tools for modeling language, and have been used both to improve the state-of-the-art in a number of tasks and to tackle new problems that were not easy in the past. This class will start with a brief overview of neural networks, then spend the majority of the class demonstrating how to apply neural networks to natural language problems. Each section class will introduce a particular problem or phenomenon in natural language, describe why it is difficult to model, and demonstrate several models that were designed to tackle this problem. In the process of doing so, the class will cover different techniques that are useful in creating models, including handling variably sized and structured sentences, efficient handling of large data, semi-supervised and unsupervised learning, structured prediction, and multilingual modeling. There are no official pre-requisites, but a natural language processing course such as 11-411, 11-611, or 11-711, or other experience with implementing natural language processing models is highly recommended.

11-751 Speech Recognition and Understanding

All Semesters: 12 units

The technology to allow humans to communicate by speech with machines or by which machines can understand when humans communicate with each other is rapidly maturing. This course provides an introduction to the theoretical tools as well as the experimental practice that has made the field what it is today. We will cover theoretical foundations, essential algorithms, major approaches, experimental strategies and current state-of-the-art systems and will introduce the participants to ongoing work in representation, algorithms and interface design. This course is suitable for graduate students with some background in computer science and electrical engineering, as well as for advanced undergraduates. Prerequisites: Sound mathematical background, knowledge of basic statistics, good computing skills. No prior experience with speech recognition is necessary. This course is primarily for graduate students in LTI, CS, Robotics, ECE, Psychology, or Computational Linguistics. Others by prior permission of instructor.

11-752 Speech II: Phonetics, Prosody, Perception and Synthesis

Spring: 12 units

The goal of the course is to give the student basic knowledge from several fields that is necessary in order to pursue research in automatic speech processing. The course will begin with a study of the acoustic content of the speech signal. The students will use the spectrographic display to examine the signal and discover its variable properties. Phones in increasingly larger contexts will be studied with the goal of understanding coarticulation. Phonological rules will be studied as a contextual aid in understanding the spectrographic display. The spectrogram will then serve as a first introduction to the basic elements of prosody. Other displays will then be used to study the three parts of prosody: amplitude, duration, and pitch. Building on these three elements, the student will then examine how the three interact in careful and spontaneous speech. Next, the students will explore perception. Topics covered will be: physical aspects of perception, psychological aspects of perception, testing perception processes, practical applications of knowledge about perception. The second part of this course will cover all aspects of speech synthesis. Students need only have a basic knowledge of speech and language processing. Some degree of programming and statistical modelling will be beneficial, but not required. Taught every other year

11-755 Machine Learning for Signal Processing

Fall: 12 units

Signal Processing is the science that deals with extraction of information from signals of various kinds. This has two distinct aspects and #8212; characterization and categorization. Traditionally, signal characterization has been performed with mathematically-driven transforms, while categorization and classification are achieved using statistical tools. Machine learning aims to design algorithms that learn about the state of the world directly from data. A increasingly popular trend has been to develop and apply machine learning techniques to both aspects of signal processing, often blurring the distinction between the two. This course discusses the use of machine learning techniques to process signals. We cover a variety of topics, from data driven approaches for characterization of signals such as audio including speech, images and video, and machine learning methods for a variety of speech and image processing problems.

11-761 Language and Statistics

Fall: 12 units

Language technologies (search, text mining, information retrieval, speech recognition, machine translation, question answering, biological sequence analysis...) are at the forefront of this century's information revolution. In addition to their use of machine learning, these technologies rely centrally on classic statistical estimation techniques. Yet most CS and engineering undergraduate programs do not prepare students in this area beyond an introductory prob and amp;stats course. This course is designed to plug this hole. The goal of "Language and Statistics" is to ground the data-driven techniques used in language technologies in sound statistical methodology. We start by formulating various language technology problems in both an information theoretic framework (the source-channel paradigm) and a Bayesian framework (the Bayes classifier). We then discuss the statistical properties of words, sentences, documents and whole languages, and the computational formalisms used to represent language. These discussions naturally lead to specific concepts in statistical estimation. Topics include: Zipf's distribution and type-token curves; point estimators, Maximum Likelihood estimation, bias and variance, sparseness, smoothing and clustering; interpolation, shrinkage, and backoff; entropy, cross entropy and mutual information; decision tree models applied to language; latent variable models and the EM algorithm; hidden Markov models; exponential models and maximum entropy; semantic modeling and dimensionality reduction; probabilistic context-free grammars and syntactic language models. The course is designed for LTI and amp; SCS graduate students, but others are welcome. CS UG upperclassmen who've taken it have done well, though they found it challenging. The 11-661 version does not require the course project. Prerequisites: Strong quantitative aptitude. Comfort with basic UG-level probability. Some programming skill.

Course Website: <http://www.cs.cmu.edu/~roni/11761/>**11-762 Language and Statistics II**

Fall: 12 units

This course will cover modern empirical methods in natural language processing. It is designed for language technologies students who want to understand statistical methodology in the language domain, and for machine learning students who want to know about current problems and solutions in text processing. Students will, upon completion, understand how statistical modeling and learning can be applied to text, be able to develop and apply new statistical models for problems in their own research, and be able to critically read papers from the major related conferences (EMNLP and ACL). A recurring theme will be the tradeoffs between computational cost, mathematical elegance, and applicability to real problems. The course will be organized around methods, with concrete tasks introduced throughout. The course is designed for SCS graduate students. Prerequisite: Language and Statistics (11-761) or permission of the instructor. Recommended: Algorithms for Natural Language Processing (11-711), Machine Learning (15-681, 15-781, or 11-746). Prerequisite: 11-761

11-763 Structured Prediction for Language and other Discrete Data

Fall: 12 units

This course seeks to cover statistical modeling techniques for discrete, structured data such as text. It brings together content previously covered in Language and Statistics 2 (11-762) and Information Extraction (10-707 and 11-748), and aims to define a canonical set of models and techniques applicable to problems in natural language processing, information extraction, and other application areas. Upon completion, students will have a broad understanding of machine learning techniques for structured outputs, will be able to develop appropriate algorithms for use in new research, and will be able to critically read related literature. The course is organized around methods, with example tasks introduced throughout.

Course Website: <http://www.cs.cmu.edu/~nasmith/SPFLODD/>**11-776 Multimodal Affective Computing**

Fall: 12 units

Humans are highly social creatures and have evolved complex mechanisms for signaling information about their thoughts, feelings, and intentions (both deliberately and reflexively). In turn, humans have also evolved complex mechanisms for receiving these signals and inferring the thoughts, feelings, and intentions of others. Proper understanding of human behavior, in all its nuance, requires careful consideration and integration of verbal, vocal, and visual information. These communication dynamics have long been studied in psychology and other social sciences. More recently, the field of multimodal affective computing has sought to enhance these studies using techniques from computer science and artificial intelligence. Common topics of study in this field include affective states, cognitive states, personality, psychopathology, social processes, and communication. As such, multimodal affective computing has broad applicability in both scientific and applied settings ranging from medicine and education to robotics and marketing. The objectives of this course are: (1) To give an overview of the components of human behavior (verbal, vocal, and visual) and the computer science areas that measure them (NLP, speech processing, and computer vision) (2) To provide foundational knowledge of psychological constructs commonly studied in multimodal affective computing (e.g., emotion, personality, and psychopathology) (3) To provide practical instruction on using statistical tools to study research hypotheses (4) To provide information about computational predictive models that integrate multimodal information from the verbal, vocal, and visual modalities (5) To give students practical experience in the computational study of human behavior and psychological constructs through an in-depth course project

11-777 Multimodal Machine Learning

Fall: 12 units

Multimodal machine learning (MMML) is a vibrant multi-disciplinary research field which addresses some of the original goals of artificial intelligence by integrating and modeling multiple communicative modalities, including linguistic, acoustic and visual messages. With the initial research on audio-visual speech recognition and more recently with language vision projects such as image and video captioning, this research field brings some unique challenges for multimodal researchers given the heterogeneity of the data and the contingency often found between modalities. The course will present the fundamental mathematical concepts in machine learning and deep learning relevant to the five main challenges in multimodal machine learning: (1) multimodal representation learning, (2) translation and mapping, (3) modality alignment, (4) multimodal fusion and (5) co-learning. These include, but not limited to, multimodal auto-encoder, deep canonical correlation analysis, multi-kernel learning, attention models and multimodal recurrent neural networks. We will also review recent papers describing state-of-the-art probabilistic models and computational algorithms for MMML and discuss the current and upcoming challenges. The course will discuss many of the recent applications of MMML including multimodal affect recognition, image and video captioning and cross-modal multimedia retrieval. This is a graduate course designed primarily for PhD and research master students at LTI, MLD, CSD, HCLL and RI; others, for example (undergraduate) students of CS or from professional master programs, are advised to seek prior permission of the instructor. It is required for students to have taken an introduction machine learning course such as 10-401, 10-601, 10-701, 11-663, 11-441, 11-641 or 11-741. Prior knowledge of deep learning is recommended."

Course Website: <https://piazza.com/cmu/fall2018/11777/home> (<https://piazza.com/cmu/fall2018/11777/home/>)

11-792 Intelligent Information Systems Project - HEINZ STUDENTS ONLY

Spring: 12 units

The Software Engineering for IS sequence combines classroom material and assignments in the fundamentals of software engineering (11-791) with a self-paced, faculty-supervised directed project (11-792). The two courses cover all elements of project design, implementation, evaluation, and documentation. Students may elect to take only 11-791; however, if both parts are taken, they should be taken in proper sequence. Prerequisite: 11-791. The course is required for VLIS students. Prerequisites: 15-393 or 11-791

11-851 Talking to Robots

Fall

Household robots need to move beyond simple programmed tasks like those a roomba, and become full-fledged digital assistants. A robotic agent that exists (physically) in the world, gains access to rich and personalized knowledge of its environment. How much do things weigh? What's fragile? Where you store the extra chocolates that you don't want anyone to find because they are just for you. Building an agent that can accomplish tasks requires the integration of a diverse set of technologies and engineering. Language models, SLAM, semantic mapping, task planning, understanding affordances, and end effector control. This course will cover both foundational works in grounding language to action and analyze (or reimplement) state-of-the-art Large Language Model based task planners.

Course Website: <https://talkingtorobots.com/11-851/>

11-877 Advanced Topics in Multimodal Machine Learning

Spring

This course is designed to be a graduate-level course covering recent research papers in multimodal machine learning, a vibrant multi-disciplinary research field which studies modeling, alignment, and fusion of heterogeneous data from multiple modalities, including language, vision, and acoustic. The course will focus on discussions and understanding of recent research papers in this field. Students are expected to have already taken 11-777 Multimodal Machine Learning course or have equivalent research experience (instructor approval required). The course is planned for 6 credit units. Optionally, students can register for 12 credit units, with the expectation to do a comprehensive research project as part of the semester. These course projects are expected to be done in teams, with the research topic to be in the realm of multimodal machine learning and pre-approved by the course instructors.

Prerequisite: 11-777 Min. grade C

11-927 MIIIS Capstone Project

Fall: 36 units

The capstone project course is a group-oriented demonstration of student skill in one or more areas covered by the degree. Typically the result of the capstone project is a major software application. The capstone project course consists of two components. The classroom component guides students in project planning, team management, development of requirements and design specifications, and software tools for managing group-oriented projects. The lab component provides project-specific technical guidance and expertise, for example in the development of a question answering system, dialog, or sentiment analysis application. Thus, each project receives two types of supervision, often from two separate members of the faculty.

Machine Learning Courses

10-301 Introduction to Machine Learning (Undergrad)

Fall and Spring: 12 units

Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10301 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation and amp; the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets and amp; Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam. 10301 is recommended for undergraduates who are not SCS majors. (SCS majors should instead take 10315.) Prerequisites (strictly enforced): strong quantitative aptitude, college probability and amp; statistics course, and programming proficiency. For learning to apply ML practically and amp; effectively, without the above prerequisites, consider 11344/05834 instead. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field. Prerequisites: 15-122 Min. grade C and (21-128 Min. grade C or 15-151 Min. grade C or 21-127 Min. grade C) and (36-217 Min. grade C or 36-218 Min. grade C or 15-359 Min. grade C or 36-219 Min. grade C or 15-259 Min. grade C or 36-225 Min. grade C or 36-235 Min. grade C or 21-325 Min. grade C)

Course Website: <http://mlcourse.org>

10-315 Introduction to Machine Learning (SCS Majors)

Fall and Spring: 12 units

Machine learning is subfield of computer science with the goal of exploring, studying, and developing learning systems, methods, and algorithms that can improve their performance with learning from data. This course is designed to give undergraduate students a one-semester-long introduction to the main principles, algorithms, and applications of machine learning and is specifically designed for the SCS undergrad majors. The topics of this course will be in part parallel with those covered in the graduate machine learning courses (10-715, 10-701, 10-601), but with a greater emphasis on applications and case studies in machine learning. After completing the course, students will be able to: *select and apply an appropriate supervised learning algorithm for classification problems (e.g., naive Bayes, perceptron, support vector machine, logistic regression). *select and apply an appropriate supervised learning algorithm for regression problems (e.g., linear regression, ridge regression). *recognize different types of unsupervised learning problems, and select and apply appropriate algorithms (e.g., clustering, linear and nonlinear dimensionality reduction). *work with probabilities (Bayes rule, conditioning, expectations, independence), linear algebra (vector and matrix operations, eigenvectors, SVD), and calculus (gradients, Jacobians) to derive machine learning methods such as linear regression, naive Bayes, and principal components analysis. *understand machine learning principles such as model selection, overfitting, and underfitting, and techniques such as cross-validation and regularization. *implement machine learning algorithms such as logistic regression via stochastic gradient descent, linear regression (using a linear algebra toolbox), perceptron, or k-means clustering. *run appropriate supervised and unsupervised learning algorithms on real and synthetic data sets and interpret the results. Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (36-218 Min. grade C or 15-359 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 36-235 Min. grade C or 36-217 Min. grade C or 36-225 Min. grade C or 15-259 Min. grade C) and (21-242 Min. grade C or 21-241 Min. grade C or 21-240 Min. grade C)

Course Website: <https://goo.gl/mmR2eL> (<https://goo.gl/mmR2eL/>)

10-335 Art and Machine Learning

Intermittent: 12 units

Ars, the Latin origin of the word art, means Art and Science. These two fields, which have been separated for a long time, are joining back together in many areas. One of those junctions is where Art and Machine Learning meet. Art in recent years has been moving forward along with the rise of new technologies and scientific discoveries. Machine Learning (ML) is one of the most cutting edge advancements in Computer Science. The popularity and accessibility of frameworks such as Google's Deep Dream system, Pikazo the neural style transfer, Kulitta AI Music Generation Framework, Deep Mind's WaveNet, Sony's Flow Machines, and recurrent neural network based language models brought great attention to the marriage of Art and ML methods. The number of ML applications that mimic famous artworks, e.g. The Next Rembrandt project, or even create original artworks such as the robot artist TAIDA's paintings, is rapidly growing. Increasing number of artists are also attempting to use ML methods in their artworks. This course is project-based and aims to introduce the crossroad of Art and Machine Learning to the broad range of students including both Art and Computer Science majors. We will offer the knowledge of examples, technologies, and issues that connect Art and Machine Learning to the students. Students will study example codes and produce creative applications/artworks using ML methods. Students do not need to have pre-existing knowledge of Machine Learning or experience of Art practice. Students are required to have basic understanding of Python and be open-minded, for example, open to learn the necessary mathematical background and open to discussions on conceptual development and artistic value of their projects.

10-403 Deep Reinforcement Learning & Control

Spring: 12 units

This course brings together many disciplines of Artificial Intelligence (including computer vision, robot control, reinforcement learning, language understanding) to show how to develop intelligent agents that can learn to sense the world and learn to act by imitating others, maximizing sparse rewards, and/or satisfying their curiosity.

Prerequisites: 10-401 Min. grade C or 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C

Course Website: <https://cmudeeprl.github.io/Spring202010403website/>

10-405 Machine Learning with Large Datasets (Undergraduate)

Spring: 12 units

Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data pre-processing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.

Prerequisites: (15-214 or 15-210 or 15-211 or 17-214) and (10-715 or 10-701 or 10-601 or 10-401 or 10-315 or 10-301)

Course Website: <https://10605.github.io/>

10-414 Deep Learning Systems: Algorithms and Implementation

Intermittent: 12 units

The goal of this course is to provide students an understanding and overview of the "full stack" of deep learning systems, ranging from the high-level modeling design of modern deep learning systems, to the basic implementation of automatic differentiation tools, to the underlying device-level implementation of efficient algorithms. Throughout the course, students will design and build from scratch a complete deep learning library, capable of efficient GPU-based operations, automatic differentiation of all implemented functions, and the necessary modules to support parameterized layers, loss functions, data loaders, and optimizers. Using these tools, students will then build several state-of-the-art modeling methods, including convolutional networks for image classification and segmentation, recurrent networks and self-attention models for sequential tasks such as language modeling, and generative models for image generation.

Prerequisites: (15-513 Min. grade C or 15-213 Min. grade C) and (21-241 Min. grade C or 21-240 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (10-715 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C)

10-417 Intermediate Deep Learning

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.

Prerequisites: 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

Course Website: <https://deeplearning-cmu-10417.github.io>

10-418 Machine Learning for Structured Data

Intermittent: 12 units

A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.

Prerequisites: 10-301 Min. grade C or 10-315 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-715 Min. grade C

10-422 Foundations of Learning, Game Theory, and Their Connections

Intermittent: 12 units

In the past decades, researchers have discovered a number of important and deep connections between machine learning theory and algorithmic game theory. This course will explore these connections, both introducing fundamental topics in each area and describing how ideas from each area can shed light on the other.

Prerequisites: (36-217 Min. grade C or 15-259 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C) and 15-251 Min. grade C and (21-241 Min. grade C or 21-242 Min. grade C or 21-240 Min. grade C)

10-425 Introduction to Convex Optimization

Intermittent: 12 units

As machine learning grows in prominence, so also has optimization become a mainstay for machine learning, particularly techniques for convex optimization. Most learning problems are formulated as optimization of some objective function, sometimes subject to constraints. This course explores the optimization algorithms used to solve these machine learning problems. We characterize the properties of the optimization problems that enable these techniques to be efficient (e.g. convexity, smoothness, linearity, separability) as well as properties that inhibit efficient optimization (e.g. nonconvexity). Core topics include first order methods (gradient descent, subgradient methods, proximal and stochastic gradient descent), duality and linear programming, and second-order/quasi-Newton methods. We also consider advanced techniques ranging from those that have spurred the growth of deep learning (e.g. adaptive gradient methods, momentum) and those that enable large-scale distributed optimization. The course will focus both on theory and practical applications, frequently drawing motivation from examples in machine learning. The course is designed so that a machine learning (ML) course could be taken after or before this one; ML is not a prerequisite. Students will gain the tools to both implement and analyze modern optimization techniques.

Prerequisites: (21-241 Min. grade C or 21-240 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-217 Min. grade C or 15-359 Min. grade C) and (21-254 Min. grade C or 11-485 Min. grade C or 21-256 Min. grade C or 21-259 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C) and (21-127 Min. grade C or 15-151 Min. grade C) and 15-122 Min. grade C

Course Website: <https://www.cs.cmu.edu/~mgormley/courses/10425>
(<https://www.cs.cmu.edu/~mgormley/courses/10425/>)

10-500 Senior Research Project

All Semesters

Register for this course if you are minoring in Machine Learning. This course is intended for research with a faculty member that would count towards the minor.

10-520 Independent Study

All Semesters

Independent Study intended to work on research with a Machine Learning faculty member.

10-600 Mathematical background for Machine Learning

Fall and Spring: 12 units

This course provides a place for students to practice the necessary mathematical background for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. Topics covered include probability, linear algebra (inner product spaces, linear operators), multivariate differential calculus, optimization, and likelihood functions. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course supersedes the two mini-courses 10-606 and 10-607.

10-601 Introduction to Machine Learning (Master's)

Fall and Spring: 12 units

Machine Learning (ML) develops computer programs that automatically improve their performance through experience. This includes learning many types of tasks based on many types of experience, e.g. spotting high-risk medical patients, recognizing speech, classifying text documents, detecting credit card fraud, or driving autonomous vehicles. 10601 covers all or most of: concept learning, decision trees, neural networks, linear learning, active learning, estimation and amp; the bias-variance tradeoff, hypothesis testing, Bayesian learning, the MDL principle, the Gibbs classifier, Naive Bayes, Bayes Nets and amp; Graphical Models, the EM algorithm, Hidden Markov Models, K-Nearest-Neighbors and nonparametric learning, reinforcement learning, bagging, boosting and discriminative training. Grading will be based on weekly or biweekly assignments (written and/or programming), a midterm, a final exam, and possibly a project (details may vary depending on the section). 10601 is recommended for quantitative master's and amp; PhD students outside MLD. Prerequisites (strictly enforced): strong quantitative aptitude, college prob and amp; stats course, and programming proficiency. For learning to apply ML practically and amp; effectively, without the above prerequisites, consider 11344/05834 instead. If you are unsure whether you have sufficient mathematical background to do well in this course, you should consider taking the minis 10-606 and 10-607 Mathematical and Computational Foundations for Machine Learning. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (15-259 Min. grade C or 36-217 Min. grade C or 36-218 Min. grade C or 36-235 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-219 Min. grade C or 15-359 Min. grade C)

Course Website: <http://mlcourse.org>

10-605 Machine Learning with Large Datasets

Fall and Spring: 12 units

Large datasets are difficult to work with for several reasons. They are difficult to visualize, and it is difficult to understand what sort of errors and biases are present in them. They are computationally expensive to process, and often the cost of learning is hard to predict - for instance, an algorithm that runs quickly in a dataset that fits in memory may be exorbitantly expensive when the dataset is too large for memory. Large datasets may also display qualitatively different behavior in terms of which learning methods produce the most accurate predictions. This course is intended to provide a student practical knowledge of, and experience with, the issues involving large datasets. Among the issues considered are: scalable learning techniques, such as streaming machine learning techniques; parallel infrastructures such as map-reduce; practical techniques for reducing the memory requirements for learning methods, such as feature hashing and Bloom filters; and techniques for analysis of programs in terms of memory, disk usage, and (for parallel methods) communication complexity. The class will include programming assignments, and a one-month short project chosen by the student. The project will be designed to compare the scalability of variant learning algorithms on datasets. An introductory course in machine learning, like 10-601 or 10-701, is a prerequisite or a co-requisite. If you plan to take this course and 10-601 concurrently please tell the instructor. The course will include several substantial programming assignments, so an additional prerequisite is 15-211, or 15-214, or comparable familiarity with Java and good programming skills. Prerequisites: (15-214 or 15-210 or 17-214 or 15-211) and (10-715 or 10-301 or 10-315 or 10-401 or 10-701 or 10-601)

Course Website: <https://10605.github.io/>

10-606 Mathematical Foundations for Machine Learning

Fall: 6 units

This course provides a place for students to practice the necessary mathematical background for further study in machine learning. Topics covered include probability (random variables, modeling with continuous and discrete distributions), linear algebra (inner product spaces, linear operators), and multivariate differential calculus (partial derivatives, matrix differentials). The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above mathematical concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-607 Computational Foundations for Machine Learning

Fall: 6 units

This course provides a place for students to practice the necessary computational background for further study in machine learning. Topics covered include computational complexity, analysis of algorithms, proof techniques, optimization, dynamic programming, recursion, and data structures. The course assumes some background in each of the above, but will review and give practice in each. (It does not provide from-scratch coverage of all of the above, which would be impossible in a course of this length.) Some coding will be required: the course will provide practice with translating the above computational concepts into concrete programs. This course is one of two minis intended to prepare students for further study in machine learning and #8212; particularly for taking 10-601 and 10-701. One of the courses 10-606 focuses on mathematical background, and the other course 10-607 focuses on computational background. Most students take both mini courses, but this is not required. 10-606 is not a prerequisite of 10-607.

10-608 Conversational Machine Learning

Intermittent: 12 units

Machine Learning today is largely about finding patterns in large amounts of data. But as personal devices that interact with us in natural language become ubiquitous (e.g., Siri, Google Now), they open an amazing possibility of letting users teach machines in natural language, similar to how we teach each other. Conversation, as an interface to machine learning systems, opens a new paradigm that both unifies several existing machine learning paradigms (e.g., active learning, supervised learning), but also brings a unique set of advantages and challenges that lie at the intersection of machine learning and natural language processing. This course will be structured as a well-defined mini-challenge (project) course. We will present you with several well-defined open problems and provide you with recently collected datasets that can get you started immediately! But you will be free to define your own problem using that data as well, or come up with your own problem entirely. There are no other constraints, and since this is a new area of research, you can (and should) be creative and as crazy in coming up with methods to tackle them. At the same time, we will provide guidance via readings and class-based hacking sessions. This course is a great way to get introduced to open problems in a collaborative and structured environment. Challenges Building a classifier with zero examples. Telling sequence to sequence models about their mistakes Letting machine learning models ask questions
Prerequisites: 10-715 Min. grade C or 10-401 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-613 Machine Learning Ethics and Society

Intermittent: 12 units

The practice of Machine Learning (ML) increasingly involves making choices that impact real people and society at large. This course covers an array of ethical, societal, and policy considerations in applying ML tools to high-stakes domains, such as employment, education, lending, criminal justice, medicine, and beyond. We will discuss: (1) the pathways through which ML can lead to or amplify problematic decision-making practices (e.g., those exhibiting discrimination, inscrutability, invasion of privacy, and beyond); (2) recent technological methods and remedies to capture and alleviate these concerns; and (3) the scope of applicability and limitations of technological remedies in the context of several contemporary application domains. The course's primary goals are: (a) to raise awareness about the social, ethical, and policy implications of ML, and (b) to prepare students to critically analyze these issues as they emerge in the ever-expanding use of ML in socially consequential domains.

Prerequisites: 10-301 or 10-315 or 10-715 or 10-601 or 10-701

Course Website: <http://www.cs.cmu.edu/~hheidari/ml-es-spring-23.html>**10-617 Intermediate Deep Learning**

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from data lies at the core of solving many AI related tasks. In the past decade, researchers across many communities, from applied statistics to engineering, computer science and neuroscience, have developed deep models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. The goal of this course is to introduce students to both the foundational ideas and the recent advances in deep learning. The first part of the course will focus on supervised learning, including neural networks, back-propagation algorithm, convolutional models, recurrent neural networks, and their extensions with applications to image recognition, video analysis, and language modelling. The second part of the course will cover unsupervised learning, including variational autoencoders, sparse-coding, Boltzmann machines, and generative adversarial networks. This course will assume a reasonable degree of mathematical maturity and will require strong programming skills.
Prerequisites: 10-601 Min. grade C or 10-701 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C

Course Website: <https://deeplearning-cmu-10417.github.io>**10-618 Machine Learning for Structured Data**

Intermittent: 12 units

A key challenge in machine learning is that of structured prediction: taking unstructured data as input and producing a structured output. Structured prediction problems abound throughout application areas such as natural language processing, speech processing, computational biology, computer vision, healthcare, and many others. In this course, we will study modern approaches to structured prediction building on probabilistic graphical models, deep learning, and search. The course will focus on three key aspects: models, inference, and learning. The models we consider will focus on both generative and discriminative models such as Bayesian networks, Markov random fields (MRFs), conditional random fields (CRFs), and deep neural networks including convolutional neural networks (CNNs) and recurrent neural networks (RNNs) and #8212; as well as hybrids of graphical models and neural networks. The course will explore approaches to exact and approximate inference: junction tree algorithm, approximate marginal inference by Markov chain Monte Carlo (MCMC) and variational methods, approximate MAP inference by integer linear programming (ILP) and search. We will explore unsupervised, semi-supervised, and supervised learning using different formulations of the learning problem: MLE, Bayesian inference, structured perceptron, M3Ns, learning to search, and autoencoders. Covered applications will include machine translation, speech recognition, DNA sequence analysis, scene understanding, medical diagnosis. This course is cross-listed as 10-418 and 10-618; students registered for 10-618 will do a course project.
Prerequisites: 10-601 Min. grade C or 10-401 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C

10-701 Introduction to Machine Learning (PhD)

Fall and Spring: 12 units

Machine learning studies the question "How can we build computer programs that automatically improve their performance through experience?" This includes learning to perform many types of tasks based on many types of experience. For example, it includes robots learning to better navigate based on experience gained by roaming their environments, medical decision aids that learn to predict which therapies work best for which diseases based on data mining of historical health records, and speech recognition systems that learn to better understand your speech based on experience listening to you. This course is designed to give PhD students a thorough grounding in the methods, mathematics and algorithms needed to do research and applications in machine learning. Students entering the class with a pre-existing working knowledge of probability, statistics and algorithms will be at an advantage, but the class has been designed so that anyone with a strong numerate background can catch up and fully participate. You can evaluate your ability to take the course via a self-assessment exam that will be made available to you after you register. If you are interested in this topic, but are not a PhD student, or are a PhD student not specializing in machine learning, you might consider the master's level course on Machine Learning, 10-601." This class may be appropriate for MS and undergrad students who are interested in the theory and algorithms behind ML. If you are unsure whether you have sufficient mathematical background to do well in this course, you should consider taking the minis 10-606/10-607 Mathematical Background for Machine Learning. You can find a link to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (15-151 Min. grade C or 21-128 Min. grade C or 21-127 Min. grade C) and (15-259 Min. grade C or 15-359 Min. grade C or 36-218 Min. grade C or 36-225 Min. grade C or 21-325 Min. grade C or 36-217 Min. grade C or 36-219 Min. grade C)

10-702 Statistical Machine Learning

Spring: 12 units

Statistical Machine Learning is a second graduate level course in advanced machine learning, assuming that students have taken Machine Learning (10-701) or Advanced Machine Learning (10-715), and Intermediate Statistics (36-705). The term "statistical" in the title reflects the emphasis on statistical theory and methodology. This course is mostly focused on methodology and theoretical foundations. It treats both the "art" of designing good learning algorithms and the "science" of analyzing an algorithm's statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. Though computation is certainly a critical component of what makes a method successful, it will not receive the same central focus as methodology and theory. We will cover topics in statistical theory that are important for researchers in machine learning, including consistency, minimax estimation, and concentration of measure. We will also cover statistical topics that may not be covered in as much depth in other machine learning courses, such as nonparametric density estimation, nonparametric regression, and Bayesian estimation. Prerequisites: (10-705 or 36-705) and (10-701 or 10-715)

Course Website: <http://www.stat.cmu.edu/~larry/=sml/>

10-703 Deep Reinforcement Learning & Control

Spring: 12 units

This course will cover latest advances in Reinforcement Learning and Imitation learning. This is a fast developing research field and an official textbook is available only for about one fourth of the course material. The rest will be taught from recent research papers. This course brings together many disciplines of Artificial Intelligence to show how to develop intelligent agent that can learn to sense the world and learn to act imitating others or maximizing sparse rewards. Particular focus will be given in incorporating visual sensory input and learning suitable visual state representations.

Prerequisites: 10-601 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-301 Min. grade B or 10-315 Min. grade B or 10-401 Min. grade B

Course Website: <https://cmudeeprl.github.io/703website/>

10-707 Advanced Deep Learning

Fall and Spring: 12 units

Models that are capable of extracting complex, hierarchical representations from high-dimensional data lie at the core of solving many ML and AI domains, such as visual object recognition, information retrieval, natural language processing, and speech perception. While the usefulness of such deep learning techniques is undisputed, our understanding of them is still in many ways nascent. The goal of this course is to introduce students to recent and exciting developments (both theoretical and practical) in these methods. This is an advanced graduate course, designed for Masters and Ph.D. level students, and will assume a substantial degree of mathematical maturity. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.

Prerequisites: 10-401 Min. grade C or 10-315 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C

10-708 Probabilistic Graphical Models

Spring: 12 units

Many of the problems in artificial intelligence, statistics, computer systems, computer vision, natural language processing, and computational biology, among many other fields, can be viewed as the search for a coherent global conclusion from local information. The probabilistic graphical models framework provides an unified view for this wide range of problems, enabling efficient inference, decision-making and learning in problems with a very large number of attributes and huge datasets. This graduate-level course will provide you with a strong foundation for both applying graphical models to complex problems and for addressing core research topics in graphical models. The class will cover three aspects: The core representation, including Bayesian and Markov networks, and dynamic Bayesian networks; probabilistic inference algorithms, both exact and approximate; and, learning methods for both the parameters and the structure of graphical models. Students entering the class should have a pre-existing working knowledge of probability, statistics, and algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. It is expected that after taking this class, the students should have obtain sufficient working knowledge of multi-variate probabilistic modeling and inference for practical applications, should be able to formulate and solve a wide range of problems in their own domain using GM, and can advance into more specialized technical literature by themselves. Students are required to have successfully completed 10701 or 10715, or an equivalent class.

Prerequisites: 10-601 Min. grade C or 10-315 Min. grade C or 10-301 Min. grade C or 10-715 Min. grade C or 10-701 Min. grade C

Course Website: <https://andrejrjsteski.github.io/10708-22/>

10-715 Advanced Introduction to Machine Learning

Fall: 12 units

Machine Learning is the primary pillar that Artificial Intelligence is built upon. This course is designed for Ph.D. students whose primary field of study is machine learning, and who intend to make machine learning methodological research a main focus of their thesis. It will give students a thorough grounding in the algorithms, mathematics, theories, and insights needed to do in-depth research and applications in machine learning. The topics of this course will in part parallel those covered in the general PhD-level machine learning course (10-701), but with a greater emphasis on depth in theory. Students entering the class are expected to have a pre-existing strong working knowledge of linear algebra, probability, statistics, and algorithms. The course will also involve programming in Python. If you are interested in this topic, but do not have the required background or are not planning to work on a PhD thesis with machine learning as the main focus, you might consider the general PhD-level Machine Learning course (10-701) or the Masters-level Machine Learning course (10-601). You can find a webpage to the Intro to ML course comparison page, which includes a self-assessment exam to help you choose which Intro to ML course to take, in the Course URL field.

Prerequisites: 15-122 Min. grade C and (21-127 Min. grade C or 15-151 Min. grade C or 21-128 Min. grade C) and (15-359 Min. grade C or 36-225 Min. grade C or 36-217 Min. grade C or 21-325 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C)

Course Website: [https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/](https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/index.html)
[index.html \(https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/\)](https://www.cs.cmu.edu/~nihars/teaching/10715-Fa23/)

10-716 Advanced Machine Learning: Theory and Methods

Spring; 12 units

Advanced Machine Learning is a graduate level course introducing the theoretical foundations of modern machine learning, as well as advanced methods and frameworks used in modern machine learning. The course assumes that students have taken graduate level introductory courses in machine learning (Introduction to Machine Learning, 10-701 or 10-715), as well as Statistics (Intermediate Statistics, 36-700 or 36-705). The course treats both the art of designing good learning algorithms, as well as the science of analyzing an algorithm's computational and statistical properties and performance guarantees. Theorems are presented together with practical aspects of methodology and intuition to help students develop tools for selecting appropriate methods and approaches to problems in their own research. We will cover advanced machine learning methods such as nonparametric and deep compositional approaches to density estimation and regression; advanced theory such as fundamentals of clustering, classification, boosting; theory and methods at the intersection of statistical and computational efficiency; as well as vignettes of theoretical results on some hot topics such as robustness and explainability.

Prerequisites: (10-701 Min. grade C or 10-715 Min. grade C) and (36-705 Min. grade C or 36-700 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~pradeep/716/>

10-725 Convex Optimization

Intermittent; 12 units

Nearly every problem in machine learning can be formulated as the optimization of some function, possibly under some set of constraints. This universal reduction may seem to suggest that such optimization tasks are intractable. Fortunately, many real world problems have special structure, such as convexity, smoothness, separability, etc., which allow us to formulate optimization problems that can often be solved efficiently. This course is designed to give a graduate-level student a thorough grounding in the formulation of optimization problems that exploit such structure, and in efficient solution methods for these problems. The main focus is on the formulation and solution of convex optimization problems, though we will discuss some recent advances in nonconvex optimization. These general concepts will also be illustrated through applications in machine learning and statistics. Students entering the class should have a pre-existing working knowledge of algorithms, though the class has been designed to allow students with a strong numerate background to catch up and fully participate. Though not required, having taken 10-701 or an equivalent machine learning or statistical modeling class is strongly encouraged, as we will use applications in machine learning and statistics to demonstrate the concepts we cover in class. Students will work on an extensive optimization-based project throughout the semester.

Prerequisites: (21-341 Min. grade C or 21-242 Min. grade C or 10-606 Min. grade C or 21-671 Min. grade C or 21-240 Min. grade C) and (21-268 Min. grade C or 21-259 Min. grade C or 21-254 Min. grade C) and (21-325 Min. grade C or 36-219 Min. grade C or 36-225 Min. grade C or 36-218 Min. grade C or 15-259 Min. grade C or 15-359 Min. grade C or 36-217 Min. grade C)

Course Website: <https://www.stat.cmu.edu/~siva/teaching/725/>

10-737 Creative AI

Intermittent

Artificial intelligence (AI) systems now generate authentic paintings, compose music pieces, and find out-of-box solutions to real-life problems in our world. Creativity, which was considered to be a moon shot for AI, does not seem to be too far any more. Is that true? Are we close to see creative AI? The answer is yes and no. We are moving closer with meaningful developments in Machine Learning, however there are several questions to be explored further to achieve the creative AI. What kind of creativity we want to represent? How do we translate creativity into what machines can understand? How do we design ML algorithms to be more creative? This course is where we explore these questions through seminars and projects. Our goal is to design computational models that present the very possibility of the creative AI. The instructors who are specialized in Machine Learning Art and Robotics lead this course together. We introduce related examples and possible methods including multi-modal data-driven learning, learning from demonstration, and combined learning from data and human demonstrations. Students are welcome to bring in their expertise and passion from diverse backgrounds to explore this topic together.

Course Website: <http://kangeunsu.com/creativeai19f/>

10-745 Scalability in Machine Learning

Fall; 12 units

The goal of this course is to provide a survey into some of the recent advances in the theory and practice of dealing with scalability issues in machine learning. We will investigate scalability issues along the following dimensions: Challenges with i) large datasets, ii) high-dimensions, and iii) complex data structure. The course is intended to prepare students to write research papers about scalability issues in machine learning. This is an advanced-level, fast-paced course that requires students to already have a solid understanding of machine learning (e.g. by taking an intro to ML class), good programming skills in Python, and being comfortable with dealing with abstract mathematical concepts and reading research papers. The course will have significant overlap with 10-405/605/805, but 10-745 will be faster-paced and go deeper into the theoretical investigations of the methods. Some of the classes will be flipped that will require students to watch a video lecture or read a research paper before the class, and the content will be discussed during the class time. The class will include a course project, HW assignments, and two-in class exams.

Prerequisites: 10-301 Min. grade B or 10-315 Min. grade B or 10-401 Min. grade B or 10-701 Min. grade B or 10-715 Min. grade B or 10-601 Min. grade B

10-777 Historical Advances in Machine Learning

Intermittent; 12 units

We will read (before class) and discuss (in class) a variety of historically important papers in ML (and to some extent AI). Not all of these were initially published in the ML/AI literature (eg: Bellman in math, VC in probability, bandits in statistics, fuzzy sets in control, optimization work in OR, etc, but now play central roles in ML and/or AI). Since "historical" is always ambiguous, we're going to go with "presented/published before the instructor was born" as a definition (pre-1988). While the content of the paper will be the primary focus, we will also attempt to understand the research context in which the paper was written. For example, what questions were other researchers asking at the time? Was the paper immediately recognized as a breakthrough or did it take a long time? Do we view the contents of the paper today as "obvious in hindsight" or is there still a lot of material in the paper that is nontrivial and even surprising or underappreciated? Who was the author, were they already relatively well known when they wrote the paper, or was it the paper itself that made them famous? What else did these authors work on before/after the paper?

Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C or 10-601 Min. grade C or 10-301 Min. grade C or 10-315 Min. grade C

10-805 Machine Learning with Large Datasets

Spring; 12 units

Large datasets pose difficulties across the machine learning pipeline. They are difficult to visualize and introduce computational, storage, and communication bottlenecks during data preprocessing and model training. Moreover, high capacity models often used in conjunction with large datasets introduce additional computational and storage hurdles during model training and inference. This course is intended to provide a student with the mathematical, algorithmic, and practical knowledge of issues involving learning with large datasets. Among the topics considered are: data cleaning, visualization, and pre-processing at scale; principles of parallel and distributed computing for machine learning; techniques for scalable deep learning; analysis of programs in terms of memory, computation, and (for parallel methods) communication complexity; and methods for low-latency inference. The class will include programming and written assignments to provide hands-on experience applying machine learning at scale. An introductory machine learning course (10-301, 10-315, 10-601, 10-701, or 10-715) is a prerequisite. A strong background in programming will also be necessary; suggested prerequisites include 15-210, 15-214, or equivalent. Students are expected to be familiar with Python or learn it during the course.

Prerequisites: (17-214 or 15-211 or 15-210 or 15-214) and (10-301 or 10-315 or 10-701 or 10-401 or 10-601 or 10-715)

Course Website: <https://10605.github.io/>

10-806 Foundations of Machine Learning and Data Science

Fall: 12 units

This course will cover fundamental topics in Machine Learning and Data Science, including powerful algorithms with provable guarantees for making sense of and generalizing from large amounts of data. The course will start by providing a basic arsenal of useful statistical and computational tools, including generalization guarantees, core algorithmic methods, and fundamental analysis models. We will examine questions such as: Under what conditions can we hope to meaningfully generalize from limited data? How can we best combine different kinds of information such as labeled and unlabeled data, leverage multiple related learning tasks, or leverage multiple types of features? What can we prove about methods for summarizing and making sense of massive datasets, especially under limited memory? We will also examine other important constraints and resources in data science including privacy, communication, and taking advantage of limited interaction. In addressing these and related questions we will make connections to statistics, algorithms, linear algebra, complexity theory, information theory, optimization, game theory, and empirical machine learning research. Topics to be covered will include: - Fundamental measures of complexity for generalization, including VC-dimension and Rademacher complexity. - Core algorithmic tools including boosting, regularization, and online optimization with connections to game theory. - Spectral methods, streaming algorithms and other approaches for handling massive data. - Foundations and algorithms for addressing important constraints or externalities such as privacy, limited memory, and communication constraints. - Foundations for modern learning paradigms including semi-supervised learning, never-ending learning, interactive learning, and deep learning.

Course Website: <http://www.cs.cmu.edu/~ninamf/courses/806/10-806-index.html> (<http://www.cs.cmu.edu/~ninamf/courses/806/10-806->)

10-807 Topics in Deep Learning

Fall: 12 units

Building intelligent machines that are capable of extracting meaningful representations from high-dimensional data lies at the core of solving many AI related tasks. In the past few years, researchers across many different communities, from applied statistics to engineering, computer science and neuroscience, have developed deep (hierarchical) models and #8212; models that are composed of several layers of nonlinear processing. An important property of these models is that they can learn useful representations by re-using and combining intermediate concepts, allowing these models to be successfully applied in a wide variety of domains, including visual object recognition, information retrieval, natural language processing, and speech perception. This is an advanced graduate course, designed for Master's and Ph.D. level students, and will assume a reasonable degree of mathematical maturity. The goal of this course is to introduce students to the recent and exciting developments of various deep learning methods. Some topics to be covered include: restricted Boltzmann machines (RBMs) and their multi-layer extensions Deep Belief Networks and Deep Boltzmann machines; sparse coding, autoencoders, variational autoencoders, convolutional neural networks, recurrent neural networks, generative adversarial networks, and attention-based models with applications in vision, NLP, and multimodal learning. We will also address mathematical issues, focusing on efficient large-scale optimization methods for inference and learning, as well as training density models with intractable partition functions. Prerequisite: ML: 10-701 or 10-715, and strong programming skills.

Prerequisites: 10-715 Min. grade C or 10-701 Min. grade C

10-822 Presentation Skills

Fall and Spring: 6 units

This course provides a forum for students to learn and refine public speaking and technical reading skills. The course will include brief workshops embedded throughout the semester to cover such things as effective structure of presentations and papers, how to give a short talk (think NIPS spotlights), "elevator" talks, structure of a research paper, conference presentations, proposal writing (think thesis and beyond), slide crafting, posters, critical evaluation, and public communications for research. Students will be expected to prepare and present a number of practice talks throughout the semester.

10-830 Machine Learning in Policy

Spring: 12 units

Machine learning, a field derived primarily from computer science and statistics, has matured and gained wide adoption over past decades. Alongside exponential increases in data measurement and availability, the ability to develop appropriate and tailored analyses is in demand. As practitioners in the social sciences consider machine learning methods, however, we are identifying limitations and externalities of the applications of machine learning techniques, such as overconfidence in settings with concept drift, lack of generalizability due to selection bias, and magnification of inequities. Machine Learning and Policy seeks to (1) demonstrate motivations and successes of machine learning, to (2) contrast them with more classical methods, and to (3) investigate the promise and cautions of machine learning for public policy. The course will cover variety of topics, including: Basics of machine learning; probability/Bayes/likelihood/conjugacy, terminology, code/algorithm design, evaluation, mathematical formulations Popular and well-performing methods; random forests/trees/ensembles, neural networks/backpropagation/embeddings/generalized adversarial networks, generalized linear models/shrinkage/convexity/basis functions, support vector machines/kernels/optimization/Lagrangian Leveraging other data sources; natural language processing/topic modeling/relational (non-i.i.d.)/relational (Markov logic networks)/temporal data Additional topics: causality/confounding/pr propensity scoring/inverse weighting/causal directed acyclic graphs, fairness/ethics, interpretation/explanation/visualization, anomaly detection, semi-supervised and active learning, reinforcement learning.

Course Website: <https://www.andrew.cmu.edu/user/jweiss2/mlp/>

10-831 Special Topics in Machine Learning and Policy

Spring: 6 units

Special Topics in Machine Learning and Policy (90-921/10-831) is intended for Ph.D. students in Heinz College, MLD, and other university departments who wish to engage in detailed exploration of a specific topic at the intersection of machine learning and public policy. Qualified master's students may also enroll with permission of the instructor; all students are expected to have some prior background in machine learning and data mining (10-601, 10-701, 90-866, 90-904/10-830, or a similar course). We will explore state-of-the-art methods for detection of emerging events and other relevant patterns in massive, high-dimensional datasets, and discuss how such methods can be applied usefully for the public good in medicine, public health, law enforcement, security, and other domains. The course will consist of lectures, discussions on current research articles and future directions, and course projects. Specific topics to be covered may include: anomaly detection, change-point detection, time series monitoring, spatial and space-time scan statistics, pattern detection in graph data, submodularity and LTSS properties for efficient pattern detection, combining multiple data sources, scaling up pattern detection to massive datasets, applications to public health, law enforcement, homeland security, and health care. A sample syllabus is available at: <http://www.cs.cmu.edu/~neill/courses/90921-S10.html>

Course Website: <http://www.cs.cmu.edu/~neill/courses/90921-S10.html>

Robotics Courses

16-161 ROB Freshman Seminar: Artificial Intelligence and Humanity

Fall and Spring: 9 units

In 1965 British mathematician I.J. Good wrote, An ultraintelligent machine could design even better machines; there would then unquestionably be an intelligence explosion, and the intelligence of man would be left far behind. As we enter an age where companies like Uber are testing driverless cars in Pittsburgh and innovative interfaces like IBMs Watson can play jeopardy and learn techniques for medical diagnoses, how are we to negotiate an intelligence explosion that for many individuals might threaten the very notions of what it means to be human? The future of human-to-machine relationships will likely define our historical epoch and yet, many young technologists and humanists underestimate the downstream impact of technological innovations on human society. Presently, we have little choice but to attend to this rapidly anxiety-ridden question. This seminar will attend to the challenge of present existential questions on what it means to be human (read not machine) in the context of a rapidly advancing technological age. We will consider human narratives throughout history that exam how governments and individual citizens defined humanity in the context of slavery and colonialism as a framework for exploring and projecting what it means to be human in the age of rapidly advancing intelligent machines. We will trace the technological advancements of the recent five decades and identify historical precedents and speculative narratives that help us to consider issues like labor, economic disparity, negotiations of power, human dignity and ethical responsibility within the context of human relations with advancing technological tools that are now coined, artificial intelligence.

16-211 Foundational Mathematics of Robotics

Fall: 12 units

This course will cover core mathematics concepts used in many advanced robotics courses at the RI. Perhaps unlike prior courses in math, the focus of this class will be to ground concepts in robotics algorithms or applications. For example: How to move and manipulate objects in 3D space (coordinate transforms, rotations). How to move an articulated robots end-effector in Cartesian space (Jacobians, gradient optimization). How to have a robot learn to recognize a vision input (neural networks, back propagation). How to plan navigate a robot optimally (dynamic programming, A* Search). Prerequisites: 21-122 and 21-241 and (21-325 or 36-225 or 36-218 or 15-259)

16-223 IDEATe Portal: Creative Kinetic Systems

Fall: 10 units

The art and science of machines which evoke human delight through physical movement is founded on a balance of form and computation. This introductory physical computing course addresses the practical design and fabrication of robots, interactive gadgets, and kinetic sculptures. The emphasis is on creating experiences for human audiences through the physical behavior of devices which embody computation with mechanism, sensing, and actuation. Specific topics include basic electronics, elementary mechanical design, embedded programming, and parametric CAD. A key objective is gaining an intuitive understanding of how information and energy move between the physical, electronic, and computational domains to create a compelling behavior. The final projects are tested in the field on children and adults. This interdisciplinary course is an IDEATe Portal Course open to students from all colleges. For students choosing to follow an IDEATe program it is an entry into either Physical Computing or Intelligent Environments. The structure of the class revolves around collaborative exercises and projects which introduce core physical computing and system engineering techniques in a human-centric context. Students apply system and design thinking across multiple domains, work together to make and test several devices, and participate in wide-ranging critique which considers both technical and artistic success.

Course Website: <https://courses.ideate.cmu.edu/16-223> (<https://courses.ideate.cmu.edu/16-223/>)

16-224 IDEATe: Re-Crafting Computational Thinking with Soft Technologies

Fall: 6 units

This course focuses on teaching introductory concepts of Robotics, Mechatronics, and Computer Science using an arts-based approach. During the course, students will build their own weaving robot, program it, and learn how weaving art is connected to computer programming and matrix mathematics. Students will also learn the history of weaving, how to design beautiful patterns, and how to extract the features of those patterns into mathematical equations and computer programs.

16-235 Fantastic Robots and How to Fold Them

Spring: 9 units

This course will focus on the basics of robotics through a hands-on approach. Students will build their own robots by designing a mechanical structure and embedding actuators, sensors, and controllers. They will then use these robots to solve a simple maze with obstacles. The course content will be delivered through lectures, workshops, and a course-long team project. In classical robotics, we explore the three main behaviors of robots through the work frame of "sense-plan-act". Robots are more than just these behaviors, and students will learn about how to make the physical embodiments of robots through an overview of design and manufacturing techniques for robot mechanisms. Students will be able to make their own mechanisms, improve the system through hardware or software, and learn how to analyze the kinematics and dynamics of these mechanisms to understand and control the motion.

Prerequisites: 15-112 Min. grade C or 15-110 Min. grade C or 15-104 Min. grade C

16-264 Humanoids

Spring: 12 units

This course surveys perception, cognition, and movement in humans, humanoid robots, and humanoid graphical characters. Application areas include more human-like robots, video game characters, and interactive movie characters.

Course Website: <http://www.cs.cmu.edu/~cga/humanoids-ugrad/>

16-299 Introduction to Feedback Control Systems

Spring: 12 units

This course is designed as a first course in feedback control systems for computer science majors. Course topics include classical linear control theory (differential equations, Laplace transforms, feedback control), linear state-space methods (controllability/observability, pole placement, LQR), nonlinear systems theory, and an introduction to control using computer learning techniques. Priorities will be given to computer science majors with robotics minor.

Prerequisites: 15-122 and 21-122

Course Website: <http://www.cs.cmu.edu/~cga/controls-intro/>

16-311 Introduction to Robotics

Spring: 12 units

This course presents an overview of robotics in practice and research with topics including vision, machine learning, motion planning, mobile mechanisms, kinematics, inverse kinematics, and sensors. In course projects, students construct LEGO robots which are driven by a microcontroller, with each project reinforcing the basic principles developed in lectures. Students usually work in teams of three: an electrical engineer, a mechanical engineer, and a computer scientist. Groups are typically self-formed except for the first lab. This course will also expose students to some of the contemporary happenings in robotics, including current robotics research, applications, robot contests and robots in the news. Students registering for this course must register for both Mon/Wed mornings and Tuesday afternoon sections.

Prerequisites: 21-240 Min. grade C or 24-311 Min. grade C or 18-202 Min. grade C or 21-260 Min. grade C or 21-241 Min. grade C

Course Website: <http://www.cs.cmu.edu/afs/cs.cmu.edu/academic/class/16311/www/current/>

16-322 Modern Sensors for Intelligent Systems

Spring: 12 units

The class aims at introducing sensing technologies for robots and other intelligent systems. The course will cover the physical principles of traditional sensors, sensor calibration and evaluation, signal processing algorithms for different sensors, and examples of sensor applications for robots or other intelligent systems. On the sensing system design part, the course will cover the common sensor fusion design and algorithms, and provide examples of sensing systems for different robots or intelligent systems, such as wearable sensors, self-driving cars, autonomous vehicles, assistant robots, and field robots in extreme conditions. The class will contain lectures, two lab sessions, and a course project.

16-350 Planning Techniques for Robotics

Spring: 12 units

Planning is one of the core components that enable robots to be autonomous. Robot planning is responsible for deciding in real-time what should the robot do next, how to do it, where should the robot move next and how to move there. This class does an in-depth study of popular planning techniques in robotics and examines their use in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students learn the theory of these methods and also implement them in a series of programming-based projects. To take the class students should have taken an Intro to Robotics class and have a good knowledge of programming and data structures.

Course Website: <http://www.cs.cmu.edu/~maxim/classes/robotplanning/>

16-362 Mobile Robot Algorithms Laboratory

Fall: 12 units

This course is an introduction to the theory and algorithms of multirotor vehicle autonomy. Students will work individually to develop a multirotor simulator in Python and C++, add sensors, plan, and perform exploration. Lectures will cover topics to advance the capabilities of the simulator. Homeworks will be designed to increase the autonomy capabilities of the multirotor vehicle. The class will culminate in an individual project that pushes the autonomy capabilities developed throughout the course and may cover multi-robot aerial autonomy, dynamic environment modeling, or advanced planning and control. In order to succeed in the course, students must have a 2nd year science/engineering level background in mathematics (matrices, vectors, coordinate systems) and have already mastered at least one object-oriented programming language like C++ or Python. When the course is over, students will have written a single software system that has been incrementally extended in functionality and regularly debugged throughout the semester.

16-371 Personalized Responsive Environments

Spring: 9 units

[IDeATe collaborative course]. Environmental factors have a significant impact on mood and productivity. Creating responsive environments necessitates the design of surroundings that are able to metamorphose in order to optimize user strengths and available resources and evolve in stride with user needs. This course will investigate the development of spaces that adapt to user preferences, moods, and task specific demands. Both the design and engineering of such personalized environments will be explored. Central course concepts will include, understanding the user, integrating various modalities (e.g., light, heat, sound) to support the changing needs of task and user, and the creation of adaptive environments that learn user preferences over time. Please note that there may be usage/materials fees associated with this course.

Prerequisites: 60-223 Min. grade C or 18-090 Min. grade C or 15-104 Min. grade C or 62-150 Min. grade C

16-374 IDeATe: Art of Robotic Special Effects

Spring: 12 units

Inspired by the early "trick" films of George Melies, this project-oriented course brings together robotics and film production technique to infuse cinema with the wonder of live magic. Students will learn the basics of film production using animatronics, camera motion control, and compositing. The projects apply these techniques to create innovative physical effects for short films, all the way from concept to post-production. The course emphasizes real-time practical effects to explore the immediacy and interactivity of improvisation and rehearsal. The robotics topics include animatronic rapid prototyping and programming human-robot collaborative performance. The course includes a brief overview of the history of special effects and robotics to set the work in context.

Course Website: <https://courses.ideate.cmu.edu/16-374> (<https://courses.ideate.cmu.edu/16-374/>)

16-375 IDeATe: Robotics for Creative Practice

Fall: 10 units

Robots come in all shapes and sizes: it is the integration of software and hardware that can make any machine surprisingly animate. This project-oriented course brings art and engineering together to build performance systems using embodied behavior as a creative medium. Students learn skills for designing, constructing and programming automated systems for storytelling and human interaction, then explore the results through exhibition and performance. Technical topics include closed-loop motion control, expressive physical and computational behavior, machine choreography, and performance conceptualization. Discussion topics include both contemporary kinetic sculpture and robotics research. This interdisciplinary course is part of IDeATe Physical Computing but is open to any student.

Prerequisites: 60-212 or 99-361 or 15-112 or 15-110 or 60-210 or 15-104

Course Website: <https://courses.ideate.cmu.edu/16-375> (<https://courses.ideate.cmu.edu/16-375/>)

16-376 IDeATe: Kinetic Fabrics

Spring: 10 units

Kinetic Fabrics brings together the fields of robotics and textiles to explore their unified creative and expressive potential. It is a wide-open frontier for kinetic art, wearable art, and architectural installation. In this course students will build a variety of performative systems combining fabrics and robotic technologies. Students will apply modular actuation and sensing to textile artworks, using software designed to facilitate fluid explorations, rapid iterations, and playful experimentation. Students will learn basic textile skills, such as hand and machine sewing, as well as gain facility and familiarity with the characteristics of multiple type of fabrics. Historical precedents as well as contemporary examples of works will support students creative growth and knowledge of the field. Students' course work will include short-term and long-term projects, sampling and prototyping, critique, and documentation. Additionally, students will organize an end-of-semester event where they will perform a developed kinetic fabric work for a public audience.

Course Website: <https://courses.ideate.cmu.edu/16-376> (<https://courses.ideate.cmu.edu/16-376/>)

16-384 Robot Kinematics and Dynamics

Fall: 12 units

Foundations and principles of robotic kinematics. Topics include transformations, forward kinematics, inverse kinematics, differential kinematics (Jacobians), manipulability, and basic equations of motion. Course also include programming on robot arms.

Prerequisites: 24-311 or 21-241 or 18-202 or 15-122 Min. grade C or 16-311

16-385 Computer Vision

Fall and Spring: 12 units

This course provides a comprehensive introduction to computer vision. Major topics include image processing, detection and recognition, geometry-based and physics-based vision, sensing and perception, and video analysis. Students will learn basic concepts of computer vision as well as hands on experience to solve real-life vision problems. This course is for undergraduate students only.

Prerequisites: (18-202 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-259 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-256 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 24-282 Min. grade C and 15-122 Min. grade C) or (21-241 Min. grade C and 21-254 Min. grade C and 15-122 Min. grade C)

Course Website: <http://www.cs.cmu.edu/~16385/>

16-397 Art, Conflict and Technology

Spring: 12 units

This course considers the period of violence in Northern Ireland from 1968 to 1998 known as The Troubles, and recent issues pertaining to sovereignty and borders caused by Brexit, Britain's proposed exit from the European Union, as a point of comparison between societies rife with strife, division and predilections to violence. We investigate the ways in which visual art to literature to theatrical performance explores and interrogates societal conflict and emergence from conflict, and how evolving technological systems influence political power dynamics and modes of artistic practice. We will use the legacy of societal conflict in Ireland and Northern Ireland to compare concepts and physical manifestations of borders, barriers and bridges in the region and in global contexts. We will examine fluctuating development of democratic processes in Ireland and Northern Ireland, individual and group public performance, and the influence of technologically crude and highly sophisticated tools on communities emerging from strife. We will use our analytical lens to focus on figurative and literal borders, barriers and bridges to explore work produced in Belfast, Derry and Dublin, alongside circumstances and artistic practice in present-day Pittsburgh, Ciudad Juarez, Jerusalem and Soweto. On a visit to Ireland and Northern Ireland over spring break, students will meet with artists, writers, legislators, community organizers, academics and ex-combatants, to learn about their past experience and current motivations. Students will analyze artistic practice, peacekeeping initiatives and performance of identity in relation to the historical framework from which it emerges in Ireland and Northern Ireland. We will use this foundation as a point of comparison to practices throughout the world. Students will process their experience and developing analytical skills by documenting their responses through original creative work.

16-421 Vision Sensors

Spring: 12 units

This course covers the fundamentals of vision cameras and other sensors - how they function, how they are built, and how to use them effectively. The course presents a journey through the fascinating five hundred year history of "camera-making" from the early 1500's "camera obscura" through the advent of film and lenses, to today's mirror-based and solid state devices (CCD, CMOS). The course includes a significant hands-on component where students learn how to use the sensors and understand, model and deal with the uncertainty (noise) in their measurements. While the first half of the course deals with conventional "single viewpoint" or "perspective" cameras, the second half of the course covers much more recent "multi-viewpoint" or "multi-perspective" cameras that includes a host of lenses and mirrors.

Prerequisites: 21-241 and 21-111

Course Website: <http://www.cs.cmu.edu/~ILIM/courses/vision-sensors/>

16-423 Designing Computer Vision Apps

Fall: 12 units

Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for students who are not familiar with computer vision, but want to come up to speed rapidly with the latest in environments, software tools and best practices for developing computer vision apps. No prior knowledge of computer vision or machine learning is required although a strong programming background is a must (at a minimum good knowledge of C/C++). Topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE), and development on iOS devices using mobile vision libraries such as GPUImage and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class is intended to generalize to other mobile platforms such as Android etc. Prerequisites: (15-213 and 21-240) or (15-213 and 21-241) or (18-213 and 18-202)

Course Website: <http://16423.courses.cs.cmu.edu>**16-425 Medical Image Analysis**

Spring: 12 units

Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/**16-441 Advanced CP/SIS: Urban Intervention**

Fall and Spring: 12 units

This course introduces students to theories, practices, and communities for critical investigation of urban spaces and play within them. The course unfolds along two parallel trajectories: research (literature review, lectures, readings, demonstrations) and design (three iterated individualized projects and a fourth larger scale final project). The first half of the course will introduce students to a wide range of theories and techniques within urban intervention that draw from fluxus, the situationist international, activism and hacktivism, as well as public policy, philosophy, psychology and economics. Students will study theoretical and practical frameworks for artistic intervention into public urban spaces, while concurrently researching actual sites and communities within Pittsburgh for experimentation. Students are required to conceptualized projects on larger (urban) scales, and find ways to implement their projects safely and legally by pursuing the necessary administrative, social, technical, financial steps required to create meaningful interventions in public spaces. This class will specifically explore three media for urban intervention: Sound Outdoor video projection Robotics, Autonomy and Mobility in the way of remote control vehicles (e.g. cars, quad-copters, etc.). For each theme, students are required to produce one project that is iterated twice or more. The undergraduate (60441) and graduate (60741) sections of the course meet concurrently and follow the same syllabus and assignments. In addition to the coursework documented in the syllabus, Graduate level students are expected to write a research paper suitable for submission to a notable relevant academic conference. This process includes a rough draft, revisions and a completed and formatted paper ready for submission

16-450 Robotics Systems Engineering

Fall: 12 units

Systems engineering examines methods of specifying, designing, analyzing and testing complex systems. In this course, principles and processes of systems engineering are introduced and applied to the development of robotic devices. The focus is on robotic system engineered to perform complex behavior. Such systems embed computing elements, integrate sensors and actuators, operate in a reliable and robust fashion, and demand rigorous engineering from conception through production. The course is organized as a progression through the systems engineering process of conceptualization, specification, design, and prototyping with consideration of verification and validation. Students completing this course will engineer a robotic system through its compete design and initial prototype. The project concept and teams can continue into the Spring-semester (16-474 Robotics Capstone) for system refinement, testing and demonstration. Prerequisites: 16-311 Min. grade B and (18-370 Min. grade B or 16-299 Min. grade B or 24-451 Min. grade B)

16-455 IDEaTE: Human-Machine Virtuosity

Spring: 12 units

[IDEaTE course] Human dexterous skill embodies a wealth of physical understanding which complements computer-based design and machine fabrication. This project-oriented course explores the duality between hand and machine through the practical development of innovative design and fabrication systems. These systems fluidly combine the expressivity and intuition of physical tools with the scalability and precision of the digital realm. Students will develop novel hybrid design and production workflows combining analog and digital processes to support the design and fabrication of their chosen projects. Specific skills covered include 3D modeling (CAD), 3D scanning, algorithmic geometric modeling, digital and robotic fabrication (additive and subtractive manufacturing), motion capture and computer based sensing, and human-robot interaction design. Areas of interest include architecture, art, and product design.

Course Website: <https://courses.ideate.cmu.edu/16-455> (<https://courses.ideate.cmu.edu/16-455/>)**16-456 Reality Computing Studio**

Fall: 12 units

[IDEaTE collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). Taught in collaboration with the school of architecture, this studio asks students to apply these technologies to real world problems such as residential design, sustainability, and infrastructure monitoring.

Course Website: <http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/>**16-457 Reality Computing II**

Spring: 12 units

[IDEaTE collaborative course] Reality computing encompasses a constellation of technologies focused around capturing reality (laser scanning, photogrammetry), working with spatial data (CAD, physical modeling, simulation), and using data to interact with and influence the physical world (augmented / virtual reality, projector systems, 3d printing, robotics). This iteration of the reality computing course will focus on "design realization": the translation from digital design to fully realized tangible artifact. Collaborating with the UDBS design studio, and within the context of a full-scale residential prototype, students will investigate how reality computing technologies can be used to accelerate and advance the process of design realization by using reality computing to understand existing homes, map design data into the real world, and highlight conflicts between design and reality. Topics of special focus within the course are residential design (John Folan) and augmented reality and robotics (Pyr Matikainen).

Course Website: <http://ideate.cmu.edu/about-ideate/departments/robotics-institute/reality-computing/>

16-461 Experimental Capture

Fall: 9 units

Performance capture is used in applications as varied as special effects in movies, animation, sports training, physical rehabilitation, and human-robot/human-computer interaction. This course will survey state-of-the-art techniques and emerging ideas, in the industry and in academia, to capture, model, and render human performances. The course will be a mix between lectures and discussion of recent progress in human motion capture and analysis. The course evaluation will be project-based, in which students will capture their own body and face motion, and build projects around the data they collect individually and as a group. We will cover: 1. Capture Techniques: We will describe and use various systems including motion capture, video-based capture, depth sensors, scanners, and eye-gaze trackers; 2. Modeling and Representation: We will cover classic and contemporary representations of face and body pose and motion, including statistical and physics-based techniques; 3. Rendering Applications: As new rendering paradigms emerge, new applications continue to develop. We will study recent progress in animation, synthesis, classification, and rehabilitation on new forms of displays. Please note that there may be usage/materials fees associated with this course.

Prerequisites: 60-422 or 15-365

16-465 Game Engine Programming

Spring: 10 units

This course is designed to help students understand, modify, and develop game engines. Game engines consist of reusable runtime and asset pipeline code. They provide game-relevant abstractions of low-level system services and libraries, making it easier to write bug-free games that work across multiple platforms. Game engines also handle artistic content, providing or integrating with authoring tools to ease the process of creating high-fidelity games. In this course, we will discuss the problems game engines attempt to solve, examine how current state-of-the-art engines address these problems, and create our own engines based on what we learn. We will cover both the content authoring and runtime aspects of engines. Coursework will consist of frequent, tightly-scoped programming and system design assignments; expeditions through game engine source code; and two group projects and #8212; one in an engine created from scratch, and one that requires modification of an existing engine. Prerequisites: Students will be expected to be fluent in at least one programming language. We will be working with C++, Javascript, and a smattering of Python. We will be using git for version control and code sharing. The assignments in the course will be designed to be completed on an OSX or Linux workstation (e.g. the IDEaTe "virtual cluster"). Working with Windows will be possible, but might require extra effort. We will be building a 3D model pipeline around Blender, but no prior knowledge of the tool will be assumed.

Prerequisites: 62-150 Min. grade C or 15-213 Min. grade C or 15-112 Min. grade C or 15-104 Min. grade C

16-467 Human Robot Interaction

Spring: 12 units

The field of human-robot interaction (HRI) is fast becoming a significant area of research in robotics. The basic objective is to create natural and effective interactions between people and robots. HRI is highly interdisciplinary, bringing together methodologies and techniques from robotics, artificial intelligence, human-computer interaction, psychology, education, and other fields. This course is primarily lecture-based, with in-class participatory mini-projects, homework assignments, a group term project that will enable students to put theory to practice, and a final. The topics covered will include technologies that enable human-robot interactions, the psychology of interaction between people and robots, how to design and conduct HRI studies, and real-world applications such as assistive robots. This course has no prerequisites, but some basic familiarity with robots is recommended (programming knowledge is not necessary, but is useful for the term project).

Course Website: <http://harp.ri.cmu.edu/courses> (<http://harp.ri.cmu.edu/courses/>)**16-469 Innovation and Shared Prosperity: Community-engagement for change**

Fall: 12 units

How might we, as a community of learners, utilize our collective talents for innovation and shift our society towards greater justice? In this course we will cover the historical and social context of university-community engagement, discuss best practices in engagement efforts, and operationalize emergent strategy alongside design justice principles. Learnings from this course will foster the growth of lifelong dispositions and habits that can empower learners to chart a course for their personal careers that are consonant with community empowerment and societal equity. This class is for individuals interested in pursuing a career at the intersection of technology and societal equity or for individuals who are interested in issues of justice and equity more broadly. Learning methods for this course will include readings, reflections, and in-class discussions. Students in this class will be asked to draw on their own experiences and to explore case studies. We also anticipate that students will directly engage with local community as facilitated through existing connections with the Center for Shared Prosperity.

16-474 Robotics Capstone

Spring: 12 units

In this course students refine the design, build, integrate, test, and demonstrate the performance of the robot they designed in the prerequisite Systems Engineering Course (16-450). The students are expected to continue to apply the process and methods of Systems Engineering to track requirements, evaluate alternatives, refine the cyberphysical architectures, plan and devise tests, verify the design, and validate system performance. In addition, the students learn and apply Project Management techniques to manage the technical scope, schedule, budget, and risks of their project. The course consists of lectures, class meetings, reviews, and a final demonstration. Lectures cover core topics in Project Management and special topics in Systems Engineering. During class meetings the students and instructor review progress on the project and discuss technical and project-execution challenges. There are three major reviews approximately at the end of each of the first three months of the semester. For each review, the students give a presentation and submit an updated version of the System Design and Development Document. The course culminates in a System Performance Validation Demonstration at the end of the semester. In addition to that the students hold a special demonstration of their robotic system for the broader Robotics community.

Prerequisite: 16-450 Min. grade C

16-480 IDEaTe: Special Topics: Creative Soft Robotics

Spring: 10 units

This experimental course offers unique topics situated at the intersection of robotics research and the arts, with a specific research focus that varies each semester. In this course, students survey the state of an emerging research area, then design and fabricate experimental systems and artworks on the theme. Students are guided through literature search and technical paper analysis to identify opportunities and techniques. The textual study spans contemporary robotics and arts literature. The project component is research-focused and explores novel techniques in design, fabrication, programming, and control. The project sequence culminates in the collaborative design of expressive robotic systems which match technical innovation with a human need or artistic expression. The initial iteration of the course focuses on soft robotics, an emerging discipline centered on devices constructed from compliant materials that incorporate sensing and actuation. The literature survey spans soft robotics and kinetic sculpture. The projects center on fabricating forms that incorporate actuators and sensors using silicone rubber cast into 3D-printed and laser-cut molds. This course is offered by IDEaTe and this iteration will satisfy minor requirements for IDEaTe Soft Technologies or IDEaTe Physical Computing.

Course Website: <https://courses.ideate.cmu.edu/16-480> (<https://courses.ideate.cmu.edu/16-480/>)**16-595 Undergraduate Independent Study**

All Semesters

For students to pursue an independent study with a Robotics Institute faculty member.

16-597 Undergraduate Reading and Research

All Semesters

Undergraduate Reading and Research enables students to gain academic credits for conducting independent studies in robotics. Students must work with a robotics faculty advisor to devise a specific objective, activities (such as reading, evaluating, designing, coding, building, or testing robotic systems) and metrics for evaluation of their performance by their advisor.

16-621 MSCV Project I

Spring: 12 units

The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

Course Website: <https://piazza.com/cmu/spring2019/16621> (<https://piazza.com/cmu/spring2019/16621/>)

16-622 MSCV Capstone

Fall: 12 units

The MSCV capstone project course is designed to give project teams additional feedback on their capstone project from peers and faculty. Every week, capstone teams will present their project PPFs (Past-Present-Future) reports. For the presenting teams, the capstone course will help develop presentation and communication skills. For the students participating as peer-reviewers, it will help develop critical thinking and the ability to give constructive advice.

16-623 Advanced Computer Vision Apps.

Fall: 12 units

Computer vision is a discipline that attempts to extract information from images and videos. Nearly every smart device on the planet has a camera, and people are increasingly interested in how to develop apps that use computer vision to perform an ever expanding list of things including: 3D mapping, photo/image search, people/object tracking, augmented reality etc. This course is intended for graduate students who are familiar with computer vision, and are keen to learn more about the applying state of the art vision methods on smart devices and embedded systems. A strong programming background is a must (at a minimum good knowledge of C/C++), topics will include using conventional computer vision software tools (OpenCV, MATLAB toolboxes, VLFeat, CAFFE, Torch 7), and development on iOS devices using mobile vision libraries such as GPUImage, Metal and fast math libraries like Armadillo and Eigen. For consistency, all app development will be in iOS and it is expected that all students participating in the class have access to an Intel-based MAC running OS X Mavericks or later. Although the coursework will be focused on a single operating system, the knowledge gained from this class will easily generalize to other mobile platforms such as Android etc.

Prerequisites: 16-720 or 16-385

Course Website: <http://16623.courses.cs.cmu.edu>

16-627 MSCV Seminar

Fall

(Only open to MSCV students.) MSCV students will be required to participate in this one-semester seminar course which will prepare them for the MSCV project starting in the Spring semester. The first part of this course will cover talks by computer vision and related faculty about the ongoing research, development programs related to Computer Vision at CMU. The second part of this course will include student/faculty tutorial on topics such as OpenCV, Dataset Creation, Mechanical Turk etc. The goal of this series is to get students acquainted with practical knowledge for a successful project. In the last month of the course, each lecture will cover upto four possible MSCV projects pitched by faculty or industrial sponsors. At the end of the course students will turn in their choices, and a faculty committee will assign them the final projects.

16-663 F1Tenth Autonomous Racing

Fall: 12 units

This hands-on, lab-centered course is for senior undergraduates and graduate students interested in the fields of artificial perception, motion planning, control theory, and applied machine learning. It is also for students interested in the burgeoning field of autonomous driving. This course introduces the students to the hardware, software and algorithms involved in building and racing an autonomous race car. Every week, students take two lectures and complete an extensive hands-on lab. By Week 6, the students will have built, programmed and driven a 1/10th scale autonomous race car. By Week 10, the students will have learned fundamental principles in perception, planning and control and will race using map-based approaches. In the last 6 weeks, they develop and implement advanced racing strategies, computer vision and machine learning algorithms that will give their team the edge in the race that concludes the course.

16-664 Self-Driving Cars: Perception & Control

Fall: 12 units

This course will teach the theoretical underpinnings of self-driving car algorithms and the practical application of the material in hands-on labs. Topics will include deep learning, computer vision, sensor fusion, localization, trajectory optimization, obstacle avoidance, and vehicle dynamics.

16-665 Robot Mobility on Air, Land, & Sea

Fall: 12 units

Required core course for MRSD first-year students. Many robots are designed to move through their environments. Three prevalent environments on earth are land, air, and water. This course will explore the modeling, control, and navigation of ground-based (wheeled and legged), air-based (rotorcraft such as quadcopters), and water-based robots.

16-675 Manufacturing Futures

Spring: 12 units

The course will introduce an array of technologies that will contribute to the future of making things and will be organized into 4 logical modules that will culminate in a team-based design project. Module 1 (Manufacturing Visions and Design Methodology): David Bourne. Module 2 (Manufacturing Processes and Process Tradeoffs): Brandon Bodily. Module 3 (Electronic Manufacturing): Rahul Panat. Module 4 (Workforce Development) : David Bourne.

16-682 Robotic Systems Development Project Course II

Fall: 15 units

Required core course for MRSD second-year students. This course is the second semester in a two-semester sequence intended to enable student teams to design and implement robot systems from the requirements development phase through implementation, verification, and demonstration of a working prototype. Teams of 4-5 students continue work on a project provided by industrial and academic partners, refine design requirements, refine or create new subsystems, and integrate and demonstrate the full system.

16-714 Special Topics: Physics-based Simulation in Robotics

Fall: 12 units

special topics physics-based simulation in robotics - description TBD

16-715 Advanced Robot Dynamics and Simulation

Fall: 12 units

This course explores the fundamental mathematics behind modeling the physics of robots, as well as state-of-the-art algorithms for robot simulation. We will review classical topics like Lagrangian mechanics and Hamilton's Principle of Least Action, as well as modern computational methods like discrete mechanics and fast linear-time algorithms for dynamics simulation. A particular focus of the course will be rigorous treatments of 3D rotations and non-smooth contact interactions (impacts and friction) that are so prevalent in robotics applications. We will use numerous case studies to explore these topics, including quadrotors, fixed-wing aircraft, wheeled vehicles, quadrupeds, humanoids, and manipulators. Homework assignments will focus on practical implementation of algorithms and a course project will encourage students to apply simulation methods to their own research.

16-720 Computer Vision

Fall and Spring: 12 units

Section A is a required core course for MRSD first-year students, and Section B is a required core course for MSCV students. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include image formation and representation, camera geometry, and calibration, computational imaging, multi-view geometry, stereo, 3D reconstruction from images, motion analysis, physics-based vision, image segmentation and object recognition. The material is based on graduate-level texts augmented with research papers, as appropriate. Evaluation is based on homeworks and a final project. The homeworks involve considerable Python programming exercises. Texts recommended but not required: Title: "Computer Vision Algorithms and Applications" Author: Richard Szeliski Series: Texts in Computer Science Publisher: Springer ISBN: 978-1-84882-934-3 Title: "Computer Vision: A Modern Approach" Authors: David Forsyth and Jean Ponce Publisher: Prentice Hall ISBN: 0-13-085198-1

Course Website: <http://www.andrew.cmu.edu/course/16-720/>

16-725 (Bio)Medical Image Analysis

Spring: 12 units

Students will gain theoretical and practical skills in 2D, 3D, and 4D biomedical image analysis, including skills relevant to general image analysis. The fundamentals of computational medical image analysis will be explored, leading to current research in applying geometry and statistics to segmentation, registration, visualization, and image understanding. Additional and related covered topics include de-noising/restoration, morphology, level sets, and shape/feature analysis. Students will develop practical experience through projects using the latest version of the National Library of Medicine Insight Toolkit (ITK) and SimpleITK, a popular open-source software library developed by a consortium of institutions including Carnegie Mellon University and the University of Pittsburgh. In addition to image analysis, the course will include interaction with radiologists and pathologist(s). *** Lectures are at CMU and students will visit clinicians at UPMC. Some or all of the class lectures may also be videoed for public distribution, but students may request to be excluded from distributed video. 16-725 is a graduate class, and 16-425 is a cross-listed undergraduate section. 16-425 is new this year, and has substantially reduced requirements for the final project and for the larger homework assignments, nor does it require shadowing the clinicians. Prerequisites: Knowledge of vector calculus, basic probability, and either C++ or python, including basic command-line familiarity and how to pass arguments to your own command-line programs. Extensive expertise with C++ and templates is not necessary, but some students may find it helpful.

Course Website: http://www.cs.cmu.edu/~galeotti/methods_course/**16-726 Learning-based Image Synthesis**

Spring: 12 units

This course introduces machine learning methods for image and video synthesis. The objectives of synthesis research vary from modeling statistical distributions of visual data, through realistic picture-perfect recreations of the world in graphics, and all the way to providing interactive tools for artistic expression. Key machine learning algorithms will be presented, ranging from classical learning methods (e.g., nearest neighbor, PCA) to deep learning models (e.g., ConvNets, NeRF, deep generative models, including GANs, VAEs, autoregressive models, and diffusion models). Finally, we will discuss image and video forensics methods for detecting synthetic content. In this class, students will learn to build practical applications and create new visual effects using their own photos and videos.

16-730 Robotics Business

Spring: 12 units

This course introduces and develops business concepts that will be useful to new and existing companies, while focusing on robotic technology exemplars. The concepts begin with how to identify a new idea to for a business that can be effectively started. Initial ideas often start as a grandiose plan to change the world and these plans are legitimately the fuel that drive new businesses forward. However, when a company starts (e.g., builds a prototype or writes a first line of code), what is the least product a company can produce that customers still want and need? This kernel and #8212; extracted from the "big plan" and #8212; is a Minimal Viable Product (MVP). Once an MVP business kernel is formulated, we will learn and study how to understand customer needs, how to market a new idea and how raise and manage money for a new business entity. These steps abridge information that can be found in an MBA curriculum, but engineers and scientists focused on the technical side will need this information to participate in the process of building companies. In parallel, we will investigate the marketplace through the stock market. The stock market is a powerful window into the world of business. In other words, when a new business is built it has to live inside the competitive environment of every other business. To understand this eco-system, we will follow several companies in-situ as they go through their own ups-and-downs within the business world. The course is project based. Each student will either build their own business concept, or they will build an improvement plan that would be targeted to improve an existing business. Professor Bourne is a founding member of the Robotics Institute(1979) and has taught business concepts within the Tepper Business School and the Robotics Institute since 1988. In addition, he is the President of his own company Design One Software.

16-735 Ethics and Robotics

Intermittent: 12 units

This course contextualizes robotics, AI, and machine learning within cultural conversation, ethics, and power relationships in society. It will draw upon "AI and Humanity" as well as numerous other texts, including Mindless by Simon Head, Drone Theory by Gr and #233;goire Chamayou, and news articles. The course will culminate in team-based design and futuring project addressing the ways in which robotic technologies will influence society and values in the near future. Our target audience is students who will participate in computer science and robotics research and can use this course to inform future research and career decisions.

Course Website: <https://vdean.github.io/16-735-ethics-robotics.html>**16-740 AI for Manipulation**

Spring: 12 units

Manipulation is the process of changing the state of objects through direct physical interactions. To perform manipulation tasks in unstructured environments, autonomous robots will need to learn about the objects in their surroundings as well as the skills required to manipulate and change the state of these objects. In this course, we explore the use of machine learning and data-driven algorithms for robot manipulation. The course introduces students to the wide variety of challenges posed by manipulation tasks, and how these challenges can be formulated as learning problems. Students are taught how these problems can be solved using machine learning techniques. The types of machine learning methods covered in this course include supervised, unsupervised, active, and reinforcement learning methods. The course includes both lectures and guided paper discussions.

16-741 Mechanics of Manipulation

Fall: 12 units

Mechanics of Manipulation is a graduate level course that dives into the fundamentals of robotic manipulation. Through this course you will learn the kinematics, statics, and dynamics of robotic manipulators as they interact with the world to accomplish tasks. You will gain experience with the intelligent use of kinematic constraint, gravity, and frictional forces. Additional topics include rigid body mechanics, automatic planning based on mechanics, deformable manipulation, and simulation of dynamic manipulation. Applications of robotic manipulation are drawn from physical human-robot interaction, manufacturing, and other domains.

Course Website: <http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/index.html> (<http://www.cs.cmu.edu/afs/cs/academic/class/16741-s07/www/>)**16-742 Geometry of Locomotion**

Fall: 12 units

This course introduces geometric methods for the analysis of locomoting systems. Focusing on the kinematics of locomoting systems, the course covers topics from differential geometry, geometric mechanics, and motion planning. Specific topics include configuration spaces, manifolds, groups, Lie groups, representations of velocity, holonomic and nonholonomic constraints, constraint curvature, response to cyclic inputs and distance metrics. The primary goal of this class is to develop an intuitive understanding of these concepts and how they are used in locomoting systems, rather than working through a set of formal proofs and derivations. We do, however, incorporate enough mathematical formalism for this class to serve as a starting point for further investigation into this topic area. We also call upon biological data, when available, and relate to the mathematical formalisms in the class.

16-745 Optimal Control and Reinforcement Learning

Spring: 12 units

This is a course about how to make robots move through and interact with their environment with speed, efficiency, and robustness. We will survey a broad range of topics from nonlinear dynamics, linear systems theory, classical optimal control, numerical optimization, state estimation, system identification, and reinforcement learning. The goal is to provide students with hands-on experience applying each of these ideas to a variety of robotic systems so that they can use them in their own research.

Course Website: <http://www.cs.cmu.edu/~cga/dynopt/>

16-748 Underactuated Robots

Fall: 12 units

People and animals move through and interact with the world in a fundamentally dynamic way. In the vast majority of cases the same cannot be said for robots. In fact, many conventional approaches to motion planning and robot control attempt to explicitly cancel out the dynamics associated with different tasks. This class will consider underactuated robots, systems that do not have full control over their state and therefore cannot be planned for or controlled via conventional methods. Our goal will be to make novel locomoting robots act more "naturally." This class will highlight the relationship between conventional ideas from deterministic motion planning and control design (e.g., dynamic programming and linear-quadratic regulators) and their contemporary counterparts, many of which help form the analytical basis for the probabilistic reasoning that underlies contemporary AI systems (e.g., POMDPs). Note that this course is inspired by and, for the most part, will follow the format of "Underactuated Robotics: Learning, Planning, and Control for Efficient and Agile Machines" created by Prof. Russ Tedrake at MIT. We will take several tangents, but the course materials provided by Prof. Tedrake through MIT Open Courseware are an incredible resource for this course (and really just in general).

16-761 Mobile Robots

Spring: 12 units

The course is targeted to senior undergraduates and graduate level students. The lectures will develop the fundamentals of this emerging sub-field of robotics by calling on the experience of practitioners, the common themes of the literature, and relevant material from more basic fields such as computer vision, mathematics, and physics.

Course Website: <http://www.frc.ri.cmu.edu/~alonzoteaching/16-761/16-761.html>

16-765 Robotics & AI for Agriculture

Spring: 12 units

Robotics and artificial intelligence technologies have the potential to increase the efficiency, long-term sustainability, and profitability of agricultural production methods. This class will introduce common aspects of agricultural systems, the AI/Robotics tools that are being used to address them, and key research challenges looking forward. Technical topics include IoT sensor networks, in-field computer vision, 3D crop mapping and modeling, mobile robot navigation, and robotic manipulation of plants. Course sessions will be split evenly between lectures by the instructor and student-led discussion of relevant papers from the contemporary research literature.

16-778 Mechatronic Design

Spring: 12 units

Mechatronics is the synergistic integration of mechanism, electronics, and computer control to achieve a functional system. This course is a semester-long multidisciplinary capstone hardware project design experience in which small (typically four-person) teams of electrical and computer engineering, mechanical engineering and robotics students deliver an end-of-course demonstration of a final integrated system capable of performing a mechatronic task. Throughout the semester, the students design, configure, implement, test and evaluate in the laboratory devices and subsystems culminating in the final integrated mechatronic system. Lectures will complement the laboratory experience with comparative surveys, operational principles, and integrated design issues associated with the spectrum of mechanism, microcontroller, electronic, sensor, and control components.

Course Website: <http://www.ece.cmu.edu/courses/items/18578.html>

16-782 Planning and Decision-making in Robotics

Fall: 12 units

Planning and Decision-making are critical components of autonomy in robotic systems. These components are responsible for making decisions that range from path planning and motion planning to coverage and task planning to taking actions that help robots understand the world around them better. This course studies underlying algorithmic techniques used for planning and decision-making in robotics and examines case studies in ground and aerial robots, humanoids, mobile manipulation platforms and multi-robot systems. The students will learn the algorithms and implement them in a series of programming-based projects.

16-785 Integrated Intelligence in Robotics: Vision Language Planning

Intermittent: 12 units

This is a project-oriented course that covers interdisciplinary topics on cognitive intelligence in robotic systems. Cognitive abilities constitute high-level, humanlike intelligence that exhibits reasoning or problem-solving skills. Such abilities as semantic perception, use of language, and task planning can be built on top of low-level robot autonomy. The topics covered generally bridge across multiple technical areas, for example, vision-language intersection and language-action/plan grounding. The project theme in Spring 2023 is "movie making" that presents various robotics and machine learning challenges ranging from content generation such as scenario generation or scene/video synthesis/editing to robotics automation such as autonomous camera control or autonomous stop-motion control. This course is composed of 50% lectures and 50% seminar classes. The course objectives will also put a special emphasis on learning research skills, e.g., problem formulation, literature review, ideation, evaluation planning, results analysis, and hypothesis verification. The course is discussion intensive, and thus attendance is required.

Course Website: <http://www.cs.cmu.edu/~jeanoh/16-785/>

16-791 Applied Data Science

Spring: 12 units

This course explores the rapidly developing field of data science in the context of its pragmatic applications. Applied Data Science strives to achieve three main goals. The first is to optimize the efficacy of decision making by human managers. The second is to maximize the utilization of available data, so that no important clue is ever missed. The third is to improve understanding of data and the underlying processes that produce it. This course aims at building skills required to systematically achieve those goals in practice. The students will gain and solidify awareness of the most prevalent contemporary methods of Data Science, and develop intuition needed for assessing practical utility of the studied topics in application scenarios. They will be able to learn how to formulate analytic tasks in support of project objectives, how to define successful analytic projects, and how to evaluate utility of existing and potential applications of the discussed technologies in practice.

16-792 Applied Machine Learning

Intermittent

This course explores the rapidly developing field of machine learning in the context of its pragmatic applications. The domain of Applied Machine Learning strives to achieve three main goals. The first is to build effective models to optimize the efficacy of decision-making. The second is to maximize the utilization of available data so that no important clue is ever missed. The third is to gain or improve an understanding of data and the underlying processes that produce it. Students are required to register for 9 units to receive credit for lectures but may also register for 12 units which will include 3 units of capstone project.

16-820 Advanced Computer Vision

Fall: 12 units

16-820 is a required core course for MSCV students and is intended to move at a slightly faster pace compared to 16-720. This course introduces the fundamental techniques used in computer vision, that is, the analysis of patterns in visual images to reconstruct and understand the objects and scenes that generated them. Topics covered include camera geometry and calibration, multi-view stereo, 3D reconstruction, image detection, segmentation, and tracking, and physics-based vision. The homeworks involve considerable Python programming exercises.

16-823 Physics-based Methods in Vision (Appearance Modeling)

Intermittent: 12 units

Everyday, we observe an extraordinary array of light and color phenomena around us, ranging from the dazzling effects of the atmosphere, the complex appearances of surfaces and materials, and underwater scenarios. For a long time, artists, scientists, and photographers have been fascinated by these effects, and have focused their attention on capturing and understanding these phenomena. In this course, we take a computational approach to modeling and analyzing these phenomena, which we collectively call "visual appearance". The first half of the course focuses on the physical fundamentals of visual appearance, while the second half of the course focuses on algorithms and applications in a variety of fields such as computer vision, graphics and remote sensing and technologies such as underwater and aerial imaging.

Prerequisites: 16-720 or 16-385 or 16-820 or 15-462

Course Website: <http://www.cs.cmu.edu/afs/cs/academic/class/16823-f06/>

16-824 Visual Learning and Recognition

Spring: 12 units

This graduate-level computer vision course focuses on representation and reasoning for large amounts of data (images, videos, associated tags, text, GPS locations, etc.) toward understanding the visual world surrounding us. We will be reading an eclectic mix of classic and recent papers on topics including Theories of Perception, Mid-level Vision (Grouping, Segmentation, Poses), Object and Scene Recognition, 3D Scene Understanding, Action Recognition, Multimodal Perception, Language and Vision Models, Deep Generative Models, Efficient Neural Networks, and more. We will cover a wide range of supervised, semi-supervised, self-supervised, and unsupervised approaches for each topic above.

Prerequisites: 16-720 Min. grade B or 16-722 Min. grade B or 10-701 Min. grade B or 16-385 Min. grade B or 15-781 Min. grade B

Course Website: <https://visual-learning.cs.cmu.edu/>

16-825 Learning for 3D Vision

Spring: 12 units

Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-831 Introduction to Robot Learning

Fall and Spring: 12 units

Robots need to make sequential decisions to operate in the world and generalize to diverse environments. How can they learn to do so? This is what we call the "robot learning" problem and it spans topics in machine learning, visual learning and reinforcement learning. In this course, we will learn the fundamentals of topics in machine/deep/visual/reinforcement-learning and how such approaches are applied to robot decision making. We will study fundamentals of: 1) machine (deep) learning with emphasis on approaches relevant for cognition, 2) reinforcement learning: model-based, model-free, on-policy (policy gradients), off-policy (q-learning), etc.; 3) imitation learning: behavior cloning, dagger, inverse RL and offline RL.; 4) visual learning geared towards cognition and decision making including topics like generative models and their use for robotics, learning from human videos, passive internet videos, language models; and 5) leveraging simulations, building differentiable simulations and how to transfer policies from simulation to the real world; 6) we will also briefly touch topics in neuroscience and psychology that provide cognitive motivations for several techniques in decision making. Throughout the course, we will look at many examples of how such methods can be applied to real robotics tasks as well as broader applications of decision making beyond robotics (such as online dialogue agents etc.). The course will provide an overview of relevant topics and open questions in the area. There will be a strong emphasis on bridging the gap between many different fields of AI. The goal is for students to get both the high-level understanding of important problems and possible solutions, as well as low level understanding of technical solutions. We hope that this course will inspire you to approach problems in cognition and embodied learning from different perspectives in your research. (As of 3/21/2023)

Course Website: https://docs.google.com/document/d/15FCdFSLj9uDKQgY__bdQgic0n2cSyyBBedVjKiRFTuM/edit?usp=sharing (https://docs.google.com/document/d/15FCdFSLj9uDKQgY__bdQgic0n2cSyyBBedVjKiRFTuM/edit?usp=sharing)

16-833 Robot Localization and Mapping

Spring: 12 units

Robot localization and mapping are fundamental capabilities for mobile robots operating in the real world. Even more challenging than these individual problems is their combination: simultaneous localization and mapping (SLAM). Robust and scalable solutions are needed that can handle the uncertainty inherent in sensor measurements, while providing localization and map estimates in real-time. We will explore suitable efficient probabilistic inference algorithms at the intersection of linear algebra and probabilistic graphical models. We will also explore state-of-the-art systems.

Course Website: <http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018> (<http://frc.ri.cmu.edu/~kaess/teaching/16833/Spring2018/>)

16-845 Insects and Robots

Fall: 12 units

This course will cover all facets of modeling, design, fabrication, and analysis of robots operating on the insect scale, with a microrobotics perspective. Insects can perform different tasks, such as manipulation or locomotion, with their small scale bodies varying from 200µm to 16cm length. Similarly, we can define a micro-robotic system as an autonomous or semi-autonomous device with features on the micron scale or that make use of micron-scale physics for mobility or manipulation of objects. Due to their small size scales, microrobots will encounter difficulties unlike their macro-scale counterparts, in terms of fabrication and autonomy. In this project-based course, our aim will be on learning the physics of scaling, fabrication paradigms, actuation and sensing strategies, with numerous case studies, and to build an insect-inspired robotic system. We will also discuss multiple applications such as surgical robotics, mobile microrobots, multi-agent systems, and micro/nano manipulation.

16-848 Hands: Design and Control for Dexterous Manipulation

Spring: 12 units

Research related to hands has increased dramatically over the past decade. Robot hand innovation may be at an all time high, with new materials and manufacturing techniques promoting an explosion of ideas. Hands have become a priority in virtual reality and telepresence. Even the study of how people use their hands is seeing the growth of new ideas and themes. With all of this attention on hands, are we close to a breakthrough in dexterity, or are we still missing some things needed for truly dexterous manipulation? In this course, we will survey robotic hands and learn about the human hand with the goal of pushing the frontiers on hand design and control for dexterous manipulation. We will consider the necessary kinematics and dynamics for dexterity, what sensors are required to carry out dexterous interactions, the importance of reflexes and compliance, the role of machine learning in grasping and manipulation, and the challenge of uncertainty. We will explore state of the art manufacturing and design techniques, including innovations in soft robotics and embedded sensing. We will examine the human hand: its structure, sensing capabilities, human grasp choice and control strategies for inspiration and benchmarking. Students will be asked to present one or two research papers, participate in discussions and short research or design exercises, and carry out a final project.

Course Website: <http://graphics.cs.cmu.edu/nsp/course/16899-s18/>

16-855 Special Topics: Tactile Sensing and Haptics

Spring: 12 units

Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans, and provide students with some hands-on experience with the popular touch sensors and devices. On the side of robot sensing, the course will cover the topics on the working principles and designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The human-machine interface is a core part of Virtual Reality (VR) and teleoperation of robots when touch is involved. The course includes lectures, research paper presentation and discussion, and course projects with tactile sensors or haptic devices.

16-873 Spacecraft Design-Build-Fly Laboratory

Fall and Spring: 12 units

Spacecraft design is a truly interdisciplinary subject that draws from every branch of engineering. This course integrates broad skillsets from mechanical engineering, electrical and computer engineering, computer science, and robotics toward the goal of designing, building, testing, and flying a small spacecraft over the course of two semesters. Students will engage directly in all aspects of the spacecraft mission lifecycle from initial requirements definition through mission operations. YES, WE ARE REALLY GOING TO LAUNCH A SATELLITE INTO SPACE AS PART OF THIS COURSE. Students will work in subsystem teams, each focusing on some aspect of the spacecraft, but will be exposed to many different disciplines and challenges. Practical, hands-on, engineering skills will be emphasized, along with building and testing physical hardware and flight software.

16-878 Special Topic: Advanced Mechatronic Design

Fall: 12 units

This course is designed for students who have a background in mechatronics by having taken a mechatronics design course or through practice. The course will be a combination of laboratories and lectures and will culminate in a class project. The topics covered will be microcontroller hardware subsystems: timer systems, PWM, interrupts; analog circuits, operational amplifiers, comparators, signal conditioning, interfacing to sensors, actuator characteristics and interfacing; C language features for embedded software, register level programming, hardware abstraction layers, event driven programming, state machines, state charts.

16-879 Medical Robotics

Fall: 12 units

This course presents an overview of medical robotics intended for graduate students and advanced undergraduates. Topics include robot kinematics, registration, navigation, tracking, treatment planning, and technical and medical aspects of specific applications. The course will include guest lectures from robotics researchers and surgeons, as well as observation of surgical cases. The course is open to non-majors who have the requisite background.

16-880 Special Topics: Engineering Haptic Interfaces

Spring: 12 units

This course focuses on addressing challenges in the field of haptics from an engineer's perspective. We will begin by studying human haptic perception and an introduction into psychophysics. We will then study the design and control of haptic systems which provide touch feedback to a user. The class format will include lectures, discussion, paper presentations, laboratories and assignments using hardware that will be shipped to the students, and a class project. This class is designed to be a graduate/advanced undergraduate course and requires a background in dynamic systems, mechatronics, and basic programming. Mechanical prototyping, robotics, and feedback control knowledge are useful skills for this class but are not required.

16-881 Seminar Deep Reinforcement Learning for Robotics

Spring: 12 units

Deep RL has a lot of promise to teach robots how to choose actions to optimize sequential decision-making problems, but how can we make deep RL work in the real world? This is a seminar course in which we read papers related to deep learning for robotics and analyze the tradeoffs between different approaches. We will read mostly state-of-the-art papers that were very recently published (e.g. recent CoRL, RSS), but we will also look at some older papers that use different approaches. The goals of the course are to 1) understand what is needed to make deep learning work for robotics 2) analyze the tradeoffs between different approaches. Each class, 2 papers will be presented. These papers will both achieve a similar robotics task but will use different learning-based approaches. The class will discuss these papers and try to understand the strengths and limitations of the approach described in each paper. The list of papers that we will be discussing this year is still to be determined; please see the website for the list of papers that we have used in past semesters: <https://sites.google.com/view/16-881-cmu/paper-lists?authuser=0> The seminar is a great followup course to 16-831, 16-884, 10-403, or 10-703.

Course Website: <https://sites.google.com/view/16-881-cmu/home?authuser=0> (<https://sites.google.com/view/16-881-cmu/home?authuser=0>)

16-882 Integrated Systems Engineering and Project Management

Spring: 12 units

Systems Engineering is a top-down, interdisciplinary, and systematic approach to conceptualizing, developing, using, and retiring systems. Project Management is a bottom-up approach that applies methods, skill, and knowledge to plan, monitor, control, and close out projects. In a broad sense, a system is a construct that consists of elements working together under well-defined requirements to achieve a unique purpose; a project is a finite team activity that aims to create a unique prototype, product, or system at a certain level of fidelity and maturity. In this course students will learn the theory, essential methods, and techniques of systems engineering and project management. They will apply these combined concepts and skills to develop a system of their choosing over the course of the semester, either independently or by collaborating with a team. Even though this course is offered by the Robotics Institute and some of its content will speak to the application of the concepts in robotic applications and systems, this course is open to and suited for all CMU students irrespective of discipline. In addition to graduate students, this course is also suited for juniors and seniors.

16-883 Special Topics: Provably Safe Robotics

Spring: 12 units

Safe autonomy has become increasingly critical in many application domains. It is important to ensure not only the safety of the ego robot, but also the safety of other agents (humans or robots) that directly interact with the autonomy. For example, robots should be safe to human workers in human-robot collaborative assembly; autonomous vehicles should be safe to other road participants. For complex autonomous systems with many degrees of freedom, safe operation depends on the correct functioning of all system components, i.e., accurate perception, optimal decision making, and safe control. This course deals with both the design and the verification of safe robotic systems. From the design perspective, we will talk about how to assure safety through planning, prediction, learning, and control. From the verification perspective, we will talk about verification of deep neural networks, safety or reachability analysis for closed loop systems, and analysis of multi-agent systems.

Course Website: <http://www.cs.cmu.edu/~cliu6/provably-safe-robotics.html>

16-884 Deep Learning for Robotics

Fall: 12 units

The goal of this course is to study relevant topics towards building intelligent robots that can learn to act and perceive in the real world. The course material should be a self-contained collection of key topics from the intersection of four research areas geared towards this common goal: a) Robot Learning and amp; Deep RL; (b) Computer Vision; (c) Control; (d) Psychology and amp; Neuroscience. This course is geared mainly towards learning and brainstorming. There will be two classes every week. In this first class, instructor will present an in-depth overview of a topic, and then in the second class, students will present instructor-assigned papers related to that topic. There will be no homeworks and just a course project. In the first quarter, we will cover state-of-the-art topics in robot learning (deep RL, inverse RL, etc.) and control (optimal control, dynamic movement primitives, etc.) by studying classical and recent papers in the area. In the second quarter, we will study the role of perception in control and vice-versa to build methods that can learn from high-dimensional raw sensory input. In the third quarter, we will discuss the state of the current understanding of how the brain integrates action and perception. We will also discuss relevant papers from ontogeny (child development literature in Psychology) and phylogeny (evolutionary development literature in Biology) of biological animals that have inspired ideas in learning and robotics. Finally, in the fourth quarter, we will bring these ideas together to brainstorm potential high-level directions that could guide the development of intelligent robots.

16-885 Special Topics: Tactile Sensing and Haptics

Fall: 12 units

Touch is an important perception modality for both humans and robots. This course aims at providing an overview of the touch perception system for both robots and humans. On the side of robot sensing, the course will cover the designs of robot touch sensors, signal processing algorithms for tactile sensing, and the application of tactile sensing in different robotic tasks; on the side of haptics, the course will introduce the neurological and cognitive study in the human haptic system, and the designs and applications of haptic devices that provide a human-machine interface. The course incorporates lectures, research paper presentations, and discussion. The combination of different modules aims to present both the basics and state-of-art research directions in the field.

16-887 Special Topic: Robotic Caregivers and Intelligent Physical Collaboration

Spring: 12 units

Robotics researchers and futurists have long dreamed of robots that can serve as caregivers. In this project-based course, you'll learn about intelligent physical human-robot collaboration and opportunities for robots that contribute to caregiving. You'll gain hands-on experience with teleoperation, autonomy, perception, navigation, manipulation, human-robot interaction, and machine learning. You'll also learn about robot design, collaborative research, and healthcare robotics.

Course Website: <https://zackory.com/rc2023/>

16-888 Special Topic: Foldable Robots: Origami-inspired design meets mechatronics

Intermittent: 12 units

The way we make robots have changed dramatically since the limitations on the material space was removed. Instead of using "nuts-and-bolts" approach that helped us to make robust, rigid, industrial robots, we can make light-weight, compliant, conformable robots out of paper, fabric, and polymers. In this class, we will explore foldable robots with a multifaceted perspective: Kinematics, design, fabrication, control, and application. We will design and manufacture mechanisms for targeted applications, such as manipulation, bio-inspiration, medical, architecture, using laminates with integrated joints and limited number of actuators.

16-889 Special Topic: Learning for 3D Vision

Spring: 12 units

Any autonomous agent we develop must perceive and act in a 3D world. The ability to infer, model, and utilize 3D representations is therefore of central importance in AI, with applications ranging from robotic manipulation and self-driving to virtual reality and image manipulation. While 3D understanding has been a longstanding goal in computer vision, it has witnessed several impressive advances due to the rapid recent progress in (deep) learning techniques e.g. differentiable rendering, single-view 3D prediction. The goal of this course is to explore this confluence of 3D Vision and Learning-based Methods.

16-890 Special Topic: Robot Cognition for Manipulation

Intermittent: 12 units

This seminar course will cover a mixture of modern and classical methods for robot cognition. We will review papers related to task planning and control using both symbolic and numeric methods. The goal of this course is to give students an overview of the current state of research on robot cognition.

16-891 Multi-Robot Planning and Coordination

Spring: 12 units

The course provides a graduate-level introduction to the field of multi-robot planning and coordination from both AI and robotics perspectives. Topics for the course include multi-robot cooperative task planning, multi-robot path/motion planning, learning for coordination, coordinating robots under uncertainty, etc. The course will particularly focus on state-of-the-art Multi-Agent Path Finding (MAPF) algorithms that can coordinate hundreds of robots with rigorous theoretical guarantees. Current applications for these technologies will be highlighted, such as mobile robot coordination for warehouses, drone swarm control, and multi-arm assembly. The course includes lectures, research paper presentations and discussions, and course projects.

16-892 Seminar: Multimodal Foundational Models

Fall: 12 units

This course will discuss recent foundation models proposed in the literature, with a focus on vision-language models. Topics include large language models, vision-language models, and vision-audio models. As time allows, this course will also discuss application of such models to visual, audio, and video content generation.

Prerequisite: 16-820

16-895 Understanding and Critiquing Generative Computer Vision

Spring: 12 units

In recent years, there have been significant advances in the field of large-scale generative modeling for visual data, such as DALL-E 2 and Stable Diffusion. This seminar course explores these advances beyond just reading and discussion. The goal is to not only inform state of the art but also develop critical and philosophical thinking among students. The course will involve reading papers, presentations, and discussions. The course will also involve reviewing and developing critical thinking.

Tepper School of Business

Isabelle Bajoux-Besnainou, Dean

Burton Hollifield, Associate Dean, Undergraduate Programs

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad 2400
www.cmu.edu/tepper/programs (http://www.cmu.edu/tepper/programs/)

The Tepper School of Business prepares tomorrow's leaders who are innovative thinkers who thrive where data and humanity connect. Empowered with the latest technology, students and alumni apply human intelligence - analytical, creative, and emotional - to unleash data's insights and lead teams toward smarter decisions. The Tepper School of Business strives for excellence in the creation and dissemination of knowledge that is grounded in scientific principles and interdisciplinary collaboration, and is directed toward improving the practice and profession of management. Since its founding in 1949 by William Larimer Mellon, the Tepper School of Business at Carnegie Mellon has been a pioneer in the field of analytical decision-making and management science.

Today, the Tepper School is most recognized for research and teaching in the areas of economics, finance, marketing, operations management, organizational behavior, and operations research. The School's notable contributions to the intellectual community include nine Nobel laureates. It is also ranked among the schools with the highest rate of academic citations in the fields of finance, operations/production, operations research, and organizational behavior. Undergraduate and graduate students gain a valuable academic foundation in the fundamental disciplines of economics, the behavioral sciences and the management sciences. In addition to emphasizing an analytical approach to problem-solving and decision-making, students integrate communication, strategic thinking, and leadership into their student experience.

Educational Objectives

The Tepper School of Business is committed to excellence at all levels of education - undergraduate, graduate, executive, and life-long learning. We recognize that educational excellence does not occur in a vacuum: it is the result of an intentionally created environment that values and takes advantage of diversity of community, thought, and experience.

The Tepper School values a diverse and inclusive community because it enriches our experiences and leads to greater creativity and innovation in our decision making. Attracting an outstanding and diverse community of faculty, staff and students, and ensuring that all members of our community have a voice and sense of belonging, will empower them to strive for excellence.

Our goal of undergraduate educational excellence is grounded on four pillars:

- creating and providing innovative and dynamic curricula;
- challenging students with opportunities and experiences that encourage them to reflect on the intersections of ethics, responsibility, and professionalism - enabling them to develop the skills needed to be successful future leaders of teams and organizations;
- transforming the classroom experience to make use of technology-enhanced learning so that students have multiple and differentiated learning models; and
- collaborating with programs and colleges across the CMU campus to create unique synergistic curricular and meta-curricular opportunities that take advantage of the breadth of CMU's excellence.

Academic Programs and Degrees Offered

The Tepper School offers degrees and programs that allow students to explore particular fields within their major.

- Bachelor of Science in Business Administration
- Bachelor of Arts in Economics
- Bachelor of Science in Economics
- Bachelor of Science in Economics and Mathematics

The Dietrich College of Humanities and Social Sciences administers the joint economics majors.

- Bachelor of Science in Economics and Politics
- Bachelor of Science in Economics and Statistics

Minors, Additional Majors and Dual Degrees

In addition to offering majors, the Tepper School offers additional majors, dual degrees and minors to all members of the Carnegie Mellon undergraduate community. These degrees are:

- Additional Major in Business Administration
- Additional Major in Economics
- Minor in Business Administration
- Minor in Business Analytics and Optimization
- Minor in Economics
- Minor in Financial Management
- Minor in Innovation and Entrepreneurship
- Minor in Operations and Supply Chain Management
- Minor in Product Management
- Dual Degree in Business Administration
- Dual Degree in Economics

Students interested in these options should consult with the appropriate Tepper School academic advisor.

Policies, Procedures and Opportunities

Academic Standing and Actions

The Tepper School believes that each student can be successful in their academic pursuits. Each student's academic pathway is unique and the Tepper School is committed to partnering with students as they learn and grow as future business leaders. At the end of each semester, a student's academic progress and performance is reviewed to determine student standing in the next academic semester. Academic actions support student success and create opportunities for students to reflect and utilize additional campus resources.

Academic Progress

Tepper students are expected to make adequate academic progress to ensure they complete their degree requirements within eight semesters. For most students, this means enrolling and completing at least 45 units per semester as they work to complete course requirements.

For business majors, academic progress is determined through these checkpoints: 1) completion of Computing @CM (99101) by the end of spring semester in the first year of enrollment; 2) by the end of a student's fourth semester in the business program, the student has successfully completed at least 40% of business foundation and business core classes (A-D grades). This translates to 8 different 9-unit courses that fulfill the requirements in the business foundation and business core courses; 3) and at the completion of a student's sixth semester in the business program, the student has a declared minor and business concentration; 4) maintain a QPA at or above 2.0; 5) complete 36+ units per semester. Students earning less than 36 units in any given semester may be considered for an academic action due to lack of academic progress.

For economics majors, academic progress is determined by these barometers: checkpoints: 1) completion of Computing @CM (99101) by the end of spring semester in the first year of enrollment; 2) and at the completion of a student's sixth semester, the student has a declared minor; 4) maintain a QPA at or above 2.0; 5) complete 36+ units per semester. Students earning less than 36 units in any given semester may be considered for an academic action due to lack of academic progress.

There are times when it is appropriate for students to enroll and complete less than 45 units and students should consult with their advisor to make the decision that is best for their immediate and long-term success. If a student enrolls and completes less than 45 units, they may be reviewed to ensure they are making adequate progress toward degree completion.

Good Standing (Departmental Status)

To graduate in eight semesters, students need to earn an average of 45 units per semester and maintain at least a 2.0 QPA.

Concern Status (Departmental Status)

Students who are not making adequate progress toward the degree, demonstrated either through QPA or semester course load, may receive a concern notification. Receiving the letter of concern notifies students that they need to engage with their advisor to reflect on their academic performance, address their progress, and determine a plan for success. Students who receive a letter of concern are required to complete an Academic Success Plan with their advisor (instructions are included in the notification).

Academic Probation (Departmental Status)

Students with a semester QPA below 2.0 and/or did not earn at least 36 factorable units are reviewed for departmental probation. Students with a cumulative QPA below 2.0 may also be placed on probation. When a student is placed on probation, the Tepper School identifies expectations during the upcoming semester to support student success that must be met. Students on probation are required to complete an Academic Success Plan with their advisor (instructions are included in the notification). Students with probation status are not permitted to overload.

Students with probation status are reviewed by the Tepper School at the end of their probation semester. Students will return to good standing when they meet their probation expectations, earn at least a 2.0 semester QPA, complete at least 36 units, and earn a cumulative QPA at or above 2.0.

Academic Suspension (University Status, Department Decision)

Students who do not meet their probation requirements qualify for academic suspension. When a student is academically suspended, the Tepper School remains committed to student success and works with students on suspension throughout the suspension in targeted ways to ensure a successful return and sustained recovery during their CMU career. When a student is placed on academic suspension, they must meet with their academic advisor and the assistant dean to develop a plan for their future success. There are three phases that define the support: phase one (immediately after academic suspension decision); phase two (during the academic suspension); phase three (preparing for the return). Information about these phases is provided in the academic suspension notification. Each phase includes advisor outreach to check-in with the student. While on academic suspension, there are impacts (<https://www.cmu.edu/hub/registrar/leaves-and-returns/impacts.html>) for students to be aware of while away.

To return from academic suspension, the Tepper School requires the student to submit material for review to determine a student's eligibility to return. Information about the materials required to return from academic suspension and the deadline for submission are communicated within the academic actions letter. (University Suspension Policy (<https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html>))

Final Probation (Departmental Status)

Following an academic suspension, Tepper School students return on final probation. When a student is placed on final probation, conditions are identified during the final probation semester that must be met to support student success. Students on final probation are required to complete an Academic Success Plan with their advisor (instructions are included in the notification) and follow additional conditions outlined by the Tepper School. Students with final probation status are reviewed by the Tepper School at the end of the semester. Failure to meet final probation conditions may lead to an academic drop from the Tepper School.

Drop (University Status)

Drop means permanent expulsion from the Tepper School. This normally follows a student's failure to meet minimal academic performance while on final probation following academic suspension.

Appeals

Students have the right to appeal Academic Actions Committee decisions to the Tepper School Dean or their appointed designee. All appeals must be received in writing by the deadline printed in the academic standing notification. Additional information about appealing an academic action decision is found in The Word: Student Handbook (<https://www.cmu.edu/student-affairs/theword/academic/appeal-of-grades-and-academic-actions.html>).

Dean's List

Tepper students who earn at least a 3.75 QPA with at least 36 factorable units (while receiving no conditional grades of "I" for Incomplete) receive Dean's List honors in fall and spring semesters. The Dean's List is published on the Tepper School website.

Graduation Requirements & Participation

In order to graduate, students must meet all course requirements specified for the program, earn a 2.00 or higher cumulative QPA, and complete the required number of earned factorable units. Students must also meet all university residence requirements and all university financial obligations before being awarded the degree and diploma. Students with less than 36 units remaining to complete in their undergraduate degree requirements are eligible to participate in graduation events. In this situation, students participate in the event but do not receive their degree and diploma until all degree requirements, university residence requirements, and all financial obligations are met.

Students qualify to graduate by meeting the following conditions:

1. Complete all degree, College, and University course requirements as shown in the Undergraduate Business Administration's and Undergraduate Economics Program's sections of this catalog.
2. Receive recommendation for their degree by the faculty of the Tepper School.
3. Meet the University's residency requirement, detailed in the Undergraduate Academic Regulations (p. 25) section of the catalog.
4. Meet all financial obligations to the university before being awarded a degree.

Modification of Graduation Requirements: A student may seek permission to modify graduation requirements by petition to the Assistant Dean and the Senior Associate Dean, Education.

Honors Thesis for Primary and Additional Majors

The Tepper School grants College Honors to graduating students who complete a senior honors thesis. The thesis is a two-semester research project with a written thesis as a final product and a presentation at the University's Meeting of the Minds research symposium in May. Eligible students must have at least 75% of their undergraduate course units and a 3.5 or higher cumulative QPA. The honors thesis is 18 units in total and students receive College Honors upon graduation. Non-Tepper students pursuing the Tepper additional majors may apply for the Tepper School's College Honors.

Independent Study

The Tepper School supports student research through credit-earning independent study with CMU faculty members. Students must be in good academic standing to be eligible for independent study. Students can earn between three and nine units of independent study for a factorable grade. The nine units are agnostic to which department awards them unless the Independent Study units are a requirement for a minor or additional major. Independent study cannot be used as a substitute for an existing course in the undergraduate catalog and cannot be a substitute for a curriculum requirement.

All independent study plans require the active involvement of a CMU faculty advisor who is responsible for the course structure and content activities, evaluation criteria, and final grade determination. Only one independent study is applied to the degree requirements. The independent study application (<https://www.cmu.edu/tepper/programs/undergraduate-business/current-students.html>) must be received by or on the add deadline of the semester during which the study is anticipated.

Integrated and Accelerated Master's Degree (3-1-1 program)

Integrated and Accelerated Master's Degree programs enable undergraduate students to earn both an undergraduate degree and a masters degree by remaining one additional year at Carnegie Mellon.

Integrated and Accelerated Master's Programs represent a considerable savings in cost and time. Students attain further breadth and/or depth of knowledge in their area of study, broadening their post-graduation career opportunities.

The Tepper School of Business offers an integrated and accelerated Master of Business Administration (MBA) to CMU undergraduate students completing either a Business Administration major or an additional major in Business Administration. Students complete 3 years as a CMU undergraduate, followed by 1 year of integrated undergraduate and graduate study, followed by 1 full year of graduate MBA coursework at Tepper. This allows students to complete the two degrees within 5 years.

To be admitted to the program, students must have applicable work or internship experience and have attained grades of B or higher in the

following courses: 70-257, 21-257 or 21-292; 73-102; 70-122; 70-371; 70-381; and 70-391.

Students must apply and be admitted to the Tepper MBA program.

Learn more about Tepper MBA admissions requirements (<https://www.cmu.edu/tepper/programs/mba/admissions/>). Interested students should apply during the junior year.

For more information on Accelerated Master's Programs, please contact the Tepper Master's Admissions Office at mba-admissions@andrew.cmu.edu or by phone 412-268-5687.

Leave of Absence

The Tepper School is committed to each student's success as they progress through the degree requirements. There may be times when it is in the student's best interest to consider a Leave of Absence in consultation with their academic advisor. W grade assignments are assigned by the academic program depending on the circumstances and timing of the Leave of Absence. When a student elects a Leave of Absence, the program remains committed to student success and works with the student throughout the time away in targeted ways to ensure a successful return to CMU. Students preparing to return from a Leave of Absence will work with the Assistant Dean and academic advisor to submit the required University paperwork and prepare for a successful return.

semester course overload

A course overload for a business student is any schedule with more than 51 units in Fall or Spring semester or more than 24 units in Summer I or Summer II. Students must petition to receive a semester overload. For Fall and Spring semesters, Tepper students petition to enroll in more than 51 units for the semester to total 57 units. For both Summer I and Summer II, students are eligible to enroll in 24 total units and can petition for 3 additional units to total 27 units per term. Students must meet the identified QPA threshold to petition for an overload. Petitions are reviewed and determined by the Tepper School. Students transferring into the Tepper School from across campus may be required to reduce their unit load to meet the Tepper School policy of 51 units per semester. New first-year or external transfer students are restricted to 50 units in their first semester and are not eligible to overload until they complete one semester. A student may lose the right to overload if their QPA drops below the threshold after an overload for the next semester has been granted.

Student Defined Major

Carnegie Mellon offers the opportunity for undergraduate students to pursue a University Student-Defined Major (<http://coursecatalog.web.cmu.edu/aboutcmu/undergraduateoptions/#studentdefinedmajortextcontainer>) (SDM). Students interested in this opportunity should begin by speaking with the Assistant Dean. The Tepper School requires students pursuing the SDM to be in good academic standing at the time the SDM is approved by Tepper as the home college.

Study Abroad

Tepper students have an array of study abroad programs available to them. Tepper offers Departmental Exchange Programs (<https://www.cmu.edu/tepper/programs/undergraduate-business/curriculum/study-abroad.html>) with business schools abroad, and many other options can be explored through CMU's Study Abroad Portal (<https://cmu-sa.terradotta.com/>). Students interested in study abroad programs should consult with a study abroad advisor in the Office of International Education and their academic advisor about the location, courses to study, and appropriate timing. Some study abroad programs have specific QPA requirements that must be met; for programs without a defined QPA requirement, the Tepper School requires students to have a cumulative QPA of 2.0 or higher to pursue a study abroad experience.

Students work with the Office of International Education (<https://www.cmu.edu/studyabroad/>) to complete the Study Abroad Transfer Credit (SATC) Form, which is required for all CMU students, prior to departure. Students must have their courses reviewed for equivalency through the transfer credit review process and study abroad transfer credit must align with transfer credit policies. If course plans change, the student must update the SATC form.

Tepper Minors

The Tepper School offers minors in Business Administration, Business Analytics and Optimization, Economics, Financial Management, Operations and Supply Chain Management, Product Management, and Innovation &

Entrepreneurship (as an IDeATE minor). Eligibility to declare one of these minors varies and students should consult the course catalog for additional information. Students enrolled in one of these minors are required to adhere to the same grading policies as primary majors. This includes the minimum QPA, letter grades for degree required courses, and the repeating courses. Upon completion of the minor degree requirements, the Tepper School certifies the minor and it is recorded on the academic transcript; minors do not appear on a student's diploma per University policy.

If a student is pursuing a business minor that requires 73102 and receives a pre-requisite waiver for 73102, 9 additional units of elective course work (70xxx) is required to ensure 54+ units are met in the minor curriculum.

If a student is pursuing an economics minor and receives a pre-requisite waiver for 73102, 9 additional units of elective course work (73xxx) is required to ensure 54+ units are met in the minor curriculum.

Faculty

FACULTY MEMBER'S NAME, Title & Dept/ProgramCarnegie Mellon, 2023-

Undergraduate Business Administration Program

Burton Hollifield, Associate Dean, Undergraduate Programs; PNC Professor of Finance; Professor of Financial Economics

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad, Suite 2400

Email: uba@andrew.cmu.edu

Advising Appointment Online Scheduler: <https://meetme.so/TepperAdvising>
www.cmu.edu/tepper/programs/undergraduate-business (<http://www.cmu.edu/tepper/programs/undergraduate-business/>)

The Business Administration Program in the Tepper School of Business is for students interested in a broad undergraduate education based on management science, quantitative reasoning, leadership development, and communications skills. The curriculum is rigorous and flexible to accommodate student interests, academic, and career goals.

The curriculum includes a central core of courses in the functional areas of business, economics, mathematics, communications, and university courses in liberal arts and sciences. Students complete an in-depth study in one functional business concentration and additional business electives. Students also complete a minor from outside the Tepper School of Business to enhance their business education. The minor promotes students' intellectual confidence and leads to the broad knowledge that can last a lifetime. The curriculum structure helps Tepper graduates become leaders in complex global business, technical, and political environments.

Beyond the major in Business Administration, we offer the opportunity for minors and additional majors to students in other programs of the university.

B.S. Degree in Business Administration

To receive the B.S. degree in Business Administration, students must complete at least 364 units, consisting of the requirements for the Business Foundations, Business Core, Concentration, Business Electives, University Core, and a Minor.

Business Foundations

| | Units |
|---|-------|
| Mathematics | |
| 21-120 Differential and Integral Calculus | 10 |
| or 21-111 Calculus I | |
| & 21-112 and Calculus II | |
| 21-256 Multivariate Analysis | 9 |
| or 21-259 Calculus in Three Dimensions | |
| 70-257 Optimization for Business | 9 |
| or 21-257 Models and Methods for Optimization | |
| or 21-292 Operations Research I | |
| Economics | |
| 73-102 Principles of Microeconomics | 9 |
| or 73-104 Principles of Microeconomics Accelerated | |
| 73-103 Principles of Macroeconomics | 9 |
| 73-230 Intermediate Microeconomics | 9 |
| or 73-240 Intermediate Macroeconomics | |
| Statistics | |
| 70-207 Probability and Statistics for Business Applications | 9 |
| or 36-200 Reasoning with Data | |
| 70-208 Regression Analysis | 9 |
| or 36-202 Methods for Statistics & Data Science | |

Business Core

| | Units |
|---------------------------|-------|
| 70-106 Business Science | 9 |
| 70-110 Business Computing | 9 |

| | |
|---|----|
| 70-122 Introduction to Accounting | 9 |
| 70-311 Organizational Behavior | 9 |
| 70-332 Business, Society and Ethics | 9 |
| 70-340 Business Communications | 9 |
| 70-345 Business Presentations | 9 |
| 70-371 Operations Management | 9 |
| 70-381 Marketing I | 9 |
| 70-391 Finance | 9 |
| 70-104 Business Leadership Endeavor I | 3 |
| 70-204 Business Leadership Endeavor II | 3 |
| 70-304 Business Leadership Endeavor III | 3 |
| 70-401 Management Game | 12 |
| or 70-447 Client Consulting Project: Strategic Management of the Enterprise | |

Concentration

The Concentration allows students to gain knowledge and expertise in a particular area of business practice. Students must complete one of the following concentrations. For students electing to complete an additional major, the concentration requirement is waived (as is the minor requirement) and students must complete three business elective courses as part of the waived concentration requirement. Concentration courses cannot double-count with any other degree requirement including the minor requirement.

- Accounting
- Business Analytics and Technologies
- Entrepreneurship
- Finance
- Global Economics and Business
- Marketing Management
- Operations Management
- Product Management
- Strategic Management

Business Electives

Students must complete 18 units of Business Electives. A business elective course is any Business course (70-xxx) that is not being used to satisfy another degree requirement. This can include 21-270 Introduction to Mathematical Finance and upper-level Economics courses (73-3xx and above). Business Electives cannot double-count with any other degree requirement including the minor.

Minor

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor and concentration requirements are waived and the student must complete 9 additional units of business elective coursework.

university core

Students are required to complete Tepper School University Core, general education coursework in the liberal arts and sciences.

Computing @ Carnegie Mellon

All undergraduate students are required to take 99-101 (<http://coursecatalog.web.cmu.edu/search/?P=99-101>) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

Business Concentrations

The concentration allows students to gain knowledge and expertise in a particular area of business practice. The coursework in the concentrations prepares students with the knowledge and skills for their career pursuits. Completing a concentration is part of the business degree requirements.

Business concentrations require at least 4 courses beyond the Business Core. Courses taken to meet concentration requirements are not allowed to double count toward any other BA degree requirements, including the minor requirement. Business concentrations may require prerequisites from courses outside the concentration.

Accounting

Required:

70-424 *Corporate Financial and Sustainability Reporting*

Choose 3 remaining courses from:

70-422 *Managerial Accounting*

70-427 *Modern Banks: Strategy and Regulation*

70-428 *Financial Statement Analysis*

70-498 *Business Language Analytics: Mining Financial Texts and Graphs*

Business Analytics and Technologies

Choose 1 from:

70-374 *Data Mining & Business Analytics*

70-467 *Machine Learning for Business Analytics*

Choose 3 remaining courses from:

70-374 *Data Mining & Business Analytics*

70-387 *Strategy for High-Tech Products and Services*

70-455 *Data Management Fundamentals*

70-458 *Advanced Data Management*

70-460 *Mathematical Models for Consulting*

70-467 *Machine Learning for Business Analytics*

70-469 *End to End Business Analytics*

70-498 *Business Language Analytics: Mining Financial Texts and Graphs*

73-366 *Designing the Digital Economy*

73-374 *Econometrics II*

Entrepreneurship

Required:

70-415 *Introduction to Entrepreneurship*

70-416 *New Venture Creation*

Choose 2 remaining courses from:

70-395 *Funding Entrepreneurial Ventures*

70-438 *Commercialization and Innovation*

70-443 *Digital Marketing and Social Media Strategy*

49-300 *Integrated Product Conceptualization*

70-509 *Independent Study in Entrepreneurship (special permission required)*

Finance

Required:

70-492 *Investment Analysis*

70-495 *Corporate Finance*

Choose 2 remaining courses from:

70-337 *Business of Blockchain*

70-353 *Financial Regulation in the Digital Age*

70-398 *International Finance*

70-484 *Data Science for Finance*

70-490 *Big Data in Finance and Machine Learning*

70-493 *Valuation and Financial Modeling*

70-497 *Derivative Securities*

70-498 *Business Language Analytics: Mining Financial Texts and Graphs*

73-338 *Financial Crises and Risk*

Global Economics and Business

Required:

73-265 *Economics and Data Science*

Choose 1 course from:

73-347 *Game Theory Applications for Economics and Business*

73-421 *Emerging Markets*

Choose 2 remaining courses from:

70-398 *International Finance*

73-338 *Financial Crises and Risk*

73-341 *Managing through Incentives*

73-365 *Firms, Market Structures, and Strategy*

73-366 *Designing the Digital Economy*

73-372 *International Money and Finance*

73-427 *Sustainability, Energy, and Environmental Economics*

product Management

Required:

70-387 *Strategy for High-Tech Products and Services*

70-452 *Introduction to Product Management*

Choose 1 course from:*

05-391 *Designing Human Centered Software*

05-410 *User-Centered Research and Evaluation*

70-389 *Design Thinking for Business: Creative Solutions for Complex Problems*

**For business majors with an HCII minor or additional major the requirement is waived and are required to take 2 courses from 70-385, 70-443, 70-481, 70-482.*

Choose 1 course from:

70-385 *Consumer Behavior*

70-443 *Digital Marketing and Social Media Strategy*

70-481 *Marketing Research*

70-482 *Pricing Strategy*

OPERATIONS MANAGEMENT

Required:

70-460 *Mathematical Models for Consulting*

70-471 *Supply Chain Management*

Choose 2 remaining courses from:

70-373 *Sustainable Operations*

70-422 *Managerial Accounting*

70-447 *Client Consulting Project: Strategic Management of the Enterprise*

70-453 *Business Technology for Consulting*

70-462 *Uncertainty and Risk Modeling*

70-474 *Quality Principles and Productivity*

70-476 *Service Operations Management*

70-477 *Real Options: Creating Value Beyond NPV*

70-493 *Valuation and Financial Modeling*

Marketing Management

Required:

70-481 *Marketing Research*

Choose 3 remaining courses from:

70-385 *Consumer Behavior*

70-387 *Strategy for High-Tech Products and Services*

70-443 *Digital Marketing and Social Media Strategy*

70-482 *Pricing Strategy*

70-483 *Advertising and Marketing Communications*

70-485 *Product and Brand Management*

Strategic Management

Choose 1 course from:

70-437 *Strategic Management and Innovation*

70-465 *Technology Strategy*

Choose 3 remaining courses from:

70-387 *Strategy for High-Tech Products and Services*

70-341 *Team Dynamics and Leadership*

70-342 *Managing Across Cultures*

70-385 *Consumer Behavior*

70-424 *Corporate Financial and Sustainability Reporting*

70-437 *Strategic Management and Innovation*

70-440 *Corporate Strategy*

70-465 *Technology Strategy*

Additional Major in Business Administration

Students are eligible to apply for the Additional Major in Business Administration after completion of the Minor in Business Administration requirements plus 21-120 Differential and Integral Calculus and 70-207 Probability and Statistics for Business Applications (or equivalent course).

The following courses are required for the Additional Major:

Business Foundations

| Mathematics | | Units |
|--------------------|--|-------|
| 21-120 | Differential and Integral Calculus | 10 |
| or 21-111 & 21-112 | Calculus I and Calculus II | |
| 21-256 | Multivariate Analysis | 9 |
| or 21-254 | Linear Algebra and Vector Calculus for Engineers | |
| or 21-259 | Calculus in Three Dimensions | |
| 70-257 | Optimization for Business | 9 |
| or 21-257 | Models and Methods for Optimization | |
| or 21-292 | Operations Research I | |
| Economics | | |
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| or 73-240 | Intermediate Macroeconomics | |
| Statistics | | |
| 70-207 | Probability and Statistics for Business Applications | 9 |
| or 36-200 | Reasoning with Data | |
| 70-208 | Regression Analysis | 9 |
| or 36-202 | Methods for Statistics & Data Science | |

Business Core

| | | |
|--------|------------------------------|----|
| 70-110 | Business Computing | 9 |
| 70-122 | Introduction to Accounting | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 70-340 | Business Communications | 9 |
| 70-345 | Business Presentations | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-391 | Finance | 9 |
| 70-401 | Management Game | 12 |

Business Electives

Students must also complete a minimum of 18 units with a maximum of 21 units in Business courses (70-xxx). The electives cannot include the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III) and Independent Study/Internship courses.

Double-Counting Restriction

Students pursuing the additional major may double-count two courses with any other major or minor requirements and are allowed unlimited double-counts for the business foundation courses. There are no double counting restrictions between the additional major and a student's home college general education requirements.

Dual Degree in Business Administration

Students intending to pursue a Dual Degree in Business Administration are required to apply for the dual degree and encouraged to consult with the Assistant Dean about their interests and application process. In addition to the student's primary degree requirements, a student accepted for Dual Degree in Business Administration is required to complete an overall number of units that exceeds the minimum unit requirement for the degree with the smaller unit requirement, by at least 90 units. Further, they must

meet all requirements for the Business Administration major including the major's University Core, concentration area, and business elective requirements. The student's primary major will substitute for the minor requirement. The student's primary major must be completed prior to or at the same time as the dual degree in Business Administration to satisfy the minor requirement.

Students pursuing the dual degree may double-count two courses with any other degree, major, or minor requirements.

Minors

The Tepper School offers several minor options for students interested in studying business - Business Administration, Business Analytics and Optimization, Financial Management, Product Management, and Operations and Supply Chain Management.

The minor in Innovation and Entrepreneurship is offered by the Tepper School through the Integrated Design, Arts, and Technology (IDeATe) network. Students must follow IDeATe policies and procedures for this minor.

Application:

Students are eligible to apply for a minor upon completion of two required courses for the minor wherein they earn a 2.0 QPA or higher in said courses.

Double-Counting:

While there are no double counting restrictions between the minor and the student's home college general education requirements, only one minor course may double-count with any other major or minor requirements. The Minor in Operations and Supply Chain Management allows an additional double-count for a total of 2 courses that may double-count with any other major or minor requirements.

Minor in Business Administration

Required:

| | | |
|-----------|---|---|
| 70-100 | Global Business ¹ | 9 |
| 70-122 | Introduction to Accounting | 9 |
| 73-102 | Principles of Microeconomics ² | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |

¹ 70-100 Global Business is intended for first-year and sophomore students only. Juniors and seniors who did not complete 70-100 and pursue the business minor replace the course with a constrained elective. 70-106 Business Science can substitute for 70-100 only if 70-106 has already been completed.

² If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of either constrained or business electives as defined by the minor.

Constrained Elective (choose one):

| | | |
|--------|-------------------------|---|
| 70-311 | Organizational Behavior | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-391 | Finance | 9 |

Business Electives: 18 units of 70-xxx courses.

- The electives cannot include: the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III), 70-207 Probability and Statistics for Business Applications, 70-208 Regression Analysis, and Independent Study/Internship courses.

Minor in Business Analytics & Optimization

Students working toward the minor must take a Multivariate Calculus prerequisite course: 21-256 Multivariate Analysis or 21-259 Calculus in Three Dimensions or 21-254 Linear Algebra and Vector Calculus for Engineers.

Modeling Uncertainty (choose one):

| | | |
|--------|--|---|
| 70-207 | Probability and Statistics for Business Applications | 9 |
| 36-200 | Reasoning with Data | 9 |

| | | |
|--------|--|---|
| 36-220 | Engineering Statistics and Quality Control | 9 |
| 36-225 | Introduction to Probability Theory | 9 |

Business Analytics and Optimization Core (required):

| | | |
|-----------|---|---|
| 70-467 | Machine Learning for Business Analytics | 9 |
| or 70-374 | Data Mining & Business Analytics | |
| or 15-388 | Practical Data Science | |
| 70-257 | Optimization for Business | 9 |
| or 21-257 | Models and Methods for Optimization | |
| or 21-292 | Operations Research I | |
| 70-469 | End to End Business Analytics | 9 |

Business Foundations Elective (choose one):

| | | |
|-----------|---|---|
| 70-122 | Introduction to Accounting | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-391 | Finance | 9 |
| 73-102 | Principles of Microeconomics ¹ | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |

¹Students may not use the 73-102 pre-requisite waiver to satisfy this requirement.

Technical Elective (choose one):

| | | |
|--------|---|---|
| 70-208 | Regression Analysis | 9 |
| 70-374 | Data Mining & Business Analytics | 9 |
| 70-455 | Data Management Fundamentals | 9 |
| 70-458 | Advanced Data Management | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| 70-462 | Uncertainty and Risk Modeling | 9 |
| 70-467 | Machine Learning for Business Analytics | 9 |
| 73-374 | Econometrics II | 9 |
| 15-388 | Practical Data Science | 9 |

Minor in Financial Management**Required:**

| | | |
|-----------|--|---|
| 70-391 | Finance | 9 |
| 70-493 | Valuation and Financial Modeling | 9 |
| 70-207 | Probability and Statistics for Business Applications | 9 |
| or 36-200 | Reasoning with Data | |
| or 36-220 | Engineering Statistics and Quality Control | |
| or 36-218 | Probability Theory for Computer Scientists | |
| or 36-225 | Introduction to Probability Theory | |
| or 36-217 | Probability Theory and Random Processes | |

Elective Courses (choose three):

| | | |
|--------|--------------------------------------|---|
| 70-398 | International Finance | 9 |
| 70-428 | Financial Statement Analysis | 9 |
| 70-492 | Investment Analysis | 9 |
| 70-495 | Corporate Finance | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-337 | Business of Blockchain | 9 |
| 21-270 | Introduction to Mathematical Finance | 9 |

Minor in Innovation & Entrepreneurship (IDeATe)

The minor in *Innovation & Entrepreneurship* is offered by the Tepper School of Business (<https://www.cmu.edu/tepper/>) as part of the Integrative Design, Arts, and Technology (<http://coursecatalog.web.cmu.edu/schools-colleges/tepper/undergraduatebusinessadministrationprogram/ideate.cmu.edu>) network. *Innovation & Entrepreneurship* is for thinkers, dreamers, problem solvers, and realists. Students quickly learn the myth of the lone creative genius is just that, a myth, and the most transformative ideas and viable businesses come from creativity and repeatable innovation processes, business strategies and models, focused work, and a commitment to

tackling real-world problems to bring value to people and the market. Through multidisciplinary coursework and a diverse cadre of faculty experts in business, technology, engineering, and design you will learn how to research, ideate, visualize, and strategize taking an idea or venture forward from multiple perspectives and collaborations. You can expect to expand as a critical thinker while adding hard and soft skills in your toolkit through hands-on learning experiences.

Specifically, you will take courses that emphasize:

- Experiential learning by doing through real-world problems, scenarios, case studies, etc.
- Critical thinking skills to understand problems, analyze strategies, determine approaches
- Multidisciplinary teamwork and collaboration
- Innovation processes, business models, strategies, and approaches
- 2D and 3D prototyping and visualizing of concepts and solutions

The IDeATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. *For more information about IDeATe, please see the Undergraduate Options (p. 21) section of the Catalog.*

Innovation & Entrepreneurship Minor Requirements**Innovation Entrepreneurial Mindset Course**

| | | |
|--------|--------------------------------------|------------|
| 70-246 | Innovation & Entrepreneurial Mindset | Units 6 |
|--------|--------------------------------------|------------|

One Portal Course

For students without prior design or product design experience, one of the following: Units

| | | |
|--------|---|---|
| 15-294 | Special Topic: Rapid Prototyping Technologies | 5 |
| 15-394 | Intermediate Rapid Prototyping | 5 |
| 51-236 | Information Design | 9 |
| 62-478 | IDeATe: digiTOOL | 9 |

For students without prior programming or computer science experience: Units

| | | |
|--------|---|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
|--------|---|----|

One Entrepreneurship Course

| | | |
|--------|----------------------------------|------------|
| 70-415 | Introduction to Entrepreneurship | Units 9 |
|--------|----------------------------------|------------|

One Venture Creation Course

| | | |
|--------|----------------------------------|------------|
| 70-395 | Funding Entrepreneurial Ventures | Units 9 |
| 70-416 | New Venture Creation | 9 |

One Innovation Process Course

| | | |
|--------|----------------------------------|------------|
| 70-438 | Commercialization and Innovation | Units 9 |
|--------|----------------------------------|------------|

One Product Development Course

| | | |
|--------|--------------------------------------|-------------|
| 49-300 | Integrated Product Conceptualization | Units 12 |
|--------|--------------------------------------|-------------|

Practice/Experience

Multiple possibilities, including:

- 70-416 New Venture Creation (if you did not take it as your Venture Creation option)
- The Swartz Center for Innovation and Entrepreneurship Innovation Scholars Program (<http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/experiential-learning/innovation-scholars/>)
- The Swartz Center for Innovation and Entrepreneurship Project Olympus Probe (<http://www.cmu.edu/swartz-center-for-entrepreneurship/education-and-resources/project-olympus/probes/student-probe->

projects.html) - Working on your own startup (12 weeks full-time in summer or throughout one full academic year);

- Students may also, with prior approval of Dave Mawhinney, fulfill this requirement through an internship with a qualifying startup or product design firm (12 weeks, full-time). If interested in this option, students should contact Dave Mawhinney (<http://www.cmu.edu/swartz-center-for-entrepreneurship/about/staff.html>) during their internship search.

Double-Counting

No more than two minor courses may double-count toward a student's major core requirements or an additional minor's core requirements.

Minor in Operations & Supply Chain Management

Required:

| | | |
|-----------|---|---|
| 73-102 | Principles of Microeconomics ¹ | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 70-371 | Operations Management | 9 |
| 70-257 | Optimization for Business | 9 |
| or 21-257 | Models and Methods for Optimization | |
| or 21-292 | Operations Research I | |
| 70-471 | Supply Chain Management | 9 |
| 70-460 | Mathematical Models for Consulting | 9 |
| or 70-477 | Real Options: Creating Value Beyond NPV | |

¹If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of business electives (70-xxx). The electives cannot include the Business Leadership Endeavor courses (70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III), 70-207 Probability and Statistics for Business Applications, 70-208 Regression Analysis and Independent Study/Internship courses.

Engineering Project Management (choose one):

| | | |
|---------------|---|----|
| 06-421 | Chemical Process Systems Design | 12 |
| 12-411 | Project Management for Engineering and Construction | 9 |
| 18-540 | Rapid Prototyping of Computer Systems | 12 |
| 18-578 | Mechatronic Design | 12 |
| 19-451-19-452 | EPP Projects I-II | 12 |
| 24-370 | Mechanical Design: Methods and Applications | 12 |
| 42-402 | BME Design Project | 9 |
| 88-451-88-452 | Policy Analysis Senior Project-Policy Analysis Senior Project | 12 |

Minor in Product Management

Required:

| | | |
|-----------|--|---|
| 70-381 | Marketing I | 9 |
| 70-387 | Strategy for High-Tech Products and Services | 9 |
| 70-452 | Introduction to Product Management | 9 |
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |

* If a student successfully passes the 73-102 waiver, this requirement is waived and the student must take an additional 9 units of minor coursework.

Course in Design Thinking (choose one):

| | | |
|--------|---|----|
| 70-389 | Design Thinking for Business: Creative Solutions for Complex Problems | 9 |
| 05-391 | Designing Human Centered Software | 12 |
| 05-410 | User-Centered Research and Evaluation | 12 |

Marketing Course (choose one):

| | | |
|--------|--|---|
| 70-385 | Consumer Behavior | 9 |
| 70-481 | Marketing Research | 9 |
| 70-482 | Pricing Strategy | 9 |
| 70-483 | Advertising and Marketing Communications | 9 |

Business Administration Policies and Procedures

Policies and procedures are listed below; additional policies and resources are in the Tepper School of Business Undergraduate Student Handbook and on the Tepper School Undergraduate Programs website.

COURSE DOUBLE COUNTS

Students cannot double count courses within the Business Administration curriculum. Courses in the concentration and business elective requirements are not allowed to double count against any other degree requirement, including minor or additional major pursuits. When choosing to double-count courses between Tepper and other academic departments, the double-count policies are determined by the other academic department for a minor, additional major, and/or dual degree. There are no double-counting restrictions between the minor and the student's home college general education requirements.

Non-Tepper students earning a minor, additional major, or dual degree in Business Administration must adhere to the policies listed in the catalog for double counting courses. Students pursuing multiple Tepper minors cannot double count beyond one course across the minors. There are no double-counting restrictions between the minor or additional major and the student's home college general education requirements.

COURSE GRADE POLICIES

Students in the business administration major must earn letter grades (A through D) for the required business courses including core courses, foundation courses, general education courses, business electives, and concentration area courses. The only degree requirement wherein a P grade is acceptable is Computing @ Carnegie Mellon (99101) or P grades awarded in the Spring 2020 Special Pass/No Pass election. Repeating courses does not replace the previously earned grade on the transcript and both grades are calculated into the QPA. Courses completed with a letter grade earn factorable units that are used to compute QPA.

DEAN'S LIST

Business Administration students who earn at least a 3.75 QPA with at least 36 factorable units (while receiving no conditional grades of "I" for Incomplete) receive Dean's List honors in fall and spring semesters. The Dean's List is published on the Tepper School website.

EXTERNAL CREDIT TRANSFER

Courses taken at higher education institutions outside of Carnegie Mellon can be considered for transfer credit if the course and the institution offering them meet a comparable level and rigor as determined by CMU faculty. Transfer credit for any Carnegie Mellon course must be approved through the appropriate review processes.

Students must earn a final grade of C or higher to receive transfer credit unless otherwise noted by an individual approval. CMU Washington Semester and CMU-Qatar courses are exempt from the transfer course policy; community college and online courses may be considered for transfer credit by the individual department policies. Students pursuing the Dual Degree in Business Administration are subject to the transfer policy for business administration primary majors.

The following courses must be taken at Carnegie Mellon: 70-106 Business Science, 70-104 Business Leadership Endeavor I, 70-204 Business Leadership Endeavor II, 70-304 Business Leadership Endeavor III, 70-401 Management Game or equivalent, 99-101 Computing @ Carnegie Mellon or First Year Writing.

Business students can transfer up to 90 units from higher education institutions to count towards the degree requirements, including study abroad.

Only 5 courses can be taken at U.S. institutions;
Only 2 courses can transfer to the business foundation courses requirements;
Only 1 course can transfer between the concentration and business elective course requirements;
Only 1 course can transfer to the business core course requirements;
Only 3 courses can transfer as general education courses.

Students who complete dual enrollment college coursework during high school must be able to produce a university/college transcript and

demonstrate that the course was taught by a college/university faculty member. Dual enrollment courses must be evaluated within the CMU equivalency processes and the courses must fall within the current transfer policy. External transfer students admitted to the Tepper School may transfer up to 182 units (including AP credit). External transfer students are not permitted to earn additional transfer credit with exceptions considered for study abroad.

Non-UBA students interested in pursuing a business minor/additional major can transfer no more than 9 units toward a minor/no more than 27 units toward the additional major requirements.

MBA COURSE ENROLLMENT

Tepper seniors with a cumulative QPA of 3.5 or higher may be eligible to enroll in Tepper graduate courses. MBA core courses are not available for undergraduate enrollment and an application for graduate course enrollment does not guarantee enrollment. Students who are interested in this option should speak with their academic advisor.

MINOR requirement for business students & additional major option

Students are required to complete a minor to earn the business degree, and some students choose to fulfill this requirement with an additional major. Each college has its own process for declaring a minor/additional major; students should work with the individual department to learn their policies. Upon official declaration of the minor/additional major, students should regularly meet with the minor/additional major advisor and their Tepper School advisor to ensure that they are meeting the requirements of the minor/additional major. If a student completes an additional major, the minor requirement is waived (as is the concentration requirement). Students must complete at least 27 plus units of business elective courses for their degree requirements if they earn an additional major. The minor/additional major is certified by the corresponding department at the time of graduation. Failure to complete the minor requirement will prevent a student in business administration from graduating.

Pass grades

There is a limit of 9 units of "P" that students may apply toward the 364 units needed for the Business Administration degree (this excludes C@CM). Exceptions are available for students who earned P grades during Spring 2020.

STUDENTS PURSUING BUSINESS MINORS OR ADDITIONAL MAJOR

For non-business students who completed 70-106 as a primary business major and subsequently pursue the business administration minor, 70-106 can substitute for 70-100. 70-106 is not an allowed substitute in any other circumstance.

Students majoring in Mathematics and concentrate in Operations Research who elect to pursue a business administration minor must take an additional constrained elective unique to the minor to avoid a violation of the double-count policy.

Transferring into Business

The Business Administration program accepts applications for transfer admission from any academic institution outside of Carnegie Mellon University on a limited basis. Students interested in transfer should contact Carnegie Mellon's Office of Admission.

The program also accepts applications for a major change from current Carnegie Mellon students who are in other academic programs to begin in either the fall or spring semester. To be considered, a student must have successfully completed a Carnegie Mellon math course required in the business program (21-120 Differential and Integral Calculus, 21-256 Multivariate Analysis, 21-254 Linear Algebra and Vector Calculus for Engineers, or 21-259 Calculus in Three Dimensions) and 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated. The application also requires a resume and personal statement. CMU students interested in changing to a Tepper major must complete the internal transfer application by the deadline which is always the last day of class in the semester preceding the desired semester for transfer. Successful transfer is limited by space.

Full-Time Faculty

MUSTAFA AKAN, Associate Professor of Operations Management - Ph.D., Northwestern University; Carnegie Mellon, 2008-

JAMES F. ALBERTUS, Assistant Professor of Finance - Ph.D., New York University; Carnegie Mellon, 2016-

LAURENCE ALES, Professor of Economics - Ph.D., University of Minnesota; Carnegie Mellon, 2008-

SEAN AMMIRATI, Distinguished Service Professor of Entrepreneurship - B.S. Computer Information Systems, Grove City College; Carnegie Mellon, 2002-

JAY APT, Professor Emeritus - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2000-

LINDA ARGOTE, Thomas Lord Professor of Organizational Behavior and Theory; Director, Center of Organizational Learning, Innovation and Knowledge - Ph.D., University of Michigan; Carnegie Mellon, 1979-

BRANDY L. AVEN, Associate Professor of Organizational Theory, Strategy, and Entrepreneurship - Ph.D., Stanford University; Carnegie Mellon, 2010-

ISABELLE BAJEUX-BESNAINOU, Dean; Richard P. Simmons Professor of Finance - Ph.D., University of Paris; Carnegie Mellon, 1989-

KATHRYN BARRACLOUGH, Teaching Professor of Finance; Associate Dean, Masters Programs - Ph.D., Australian National University; Carnegie Mellon, 2015-

JAMES A. BEST, Assistant Professor of Economics - Ph.D., University of Edinburgh; Carnegie Mellon, 2018-

CARLA BEVINS, Associate Teaching Professor of Business Communication - Ph.D., University of Kentucky; Carnegie Mellon, 2017-

ROBERT BLATTBERG, Timothy W. McGuire Distinguished Service Professor of Marketing - Ph.D., Carnegie Mellon University; Carnegie Mellon, 1971-

PETER BOATWRIGHT, Allan D. Shocker Professor of Marketing and New Product Development; Co-Director, Integrated Innovation Institute - Ph.D., University of Chicago; Carnegie Mellon, 1997-

PIETRO BONALDI, Assistant Professor of Accounting - Ph.D., University of Chicago; Carnegie Mellon, 2017-

ARTHUR BONI, The John R. Thorne Distinguished Career Professor of Entrepreneurship, Emeritus - Ph.D., University of California, San Diego;

SERRA BORANBAY-AKAN, Assistant Teaching Professor of Economics - Ph.D., Northwestern University; Carnegie Mellon, 2013-

CLARA BURKE, Associate Teaching Professor of Business Communication - Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2015-

DAVID CHILDERS, Assistant Professor of Economics - Ph.D., Yale University; Carnegie Mellon, 2017-

SOO-HAENG CHO, IBM Professor of Operations Management - Ph.D., University of California, Los Angeles; Carnegie Mellon, 2008-

ROSALIND M. CHOW, Associate Professor of Organizational Behavior and Theory - Ph.D., Stanford University; Carnegie Mellon, 2008-

MATTIA CIOLLARO, Assistant Teaching Professor of Business Analytics - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022-

TAYA R. COHEN, Associate Professor of Organizational Behavior and Business Ethics - Ph.D., University North Carolina, Chapel Hill; Carnegie Mellon, 2010-

GERARD CORNUÉJOLS, IBM University Professor of Operations Research, Emeritus - Ph.D., Cornell University; Carnegie Mellon, 1978-

ROBERT DALTON, Associate Teaching Professor of Economics, Emeritus - Ph.D., University of Missouri; Carnegie Mellon, 1985-

ROBERT M. DAMMON, Richard C. Green Professor of Financial Economics - Ph.D., University of Wisconsin, Madison; Carnegie Mellon, 1984-

EMILY DEJEU, Assistant Teaching Professor of Business Communication - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022-

MATTHEW DENES, Assistant Professor of Finance and Entrepreneurship - Ph.D., University of Washington; Carnegie Mellon, 2017-

ABBE DEPRETIS, Assistant Teaching Professor of Business Communication - Ph.D., University of Maryland; Carnegie Mellon, 2017-

TIMOTHY P. DERDINGER, Associate Professor of Marketing and Strategy - Ph.D., University of Southern California; Carnegie Mellon, 2009-

- KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979–
- DENNIS N. EPPEL, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974–
- SELMAN EROL, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2017–
- MARK FICHMAN, Associate Professor of Organizational Behavior and Theory, Emeritus – Ph.D., University of Michigan; Carnegie Mellon, 1980–
- CHRISTINA FONG, Research Scientist, Department of Social and Decision Sciences, Dietrich College – Ph.D., University of Massachusetts; Carnegie Mellon, 2000–
- MOHSEN FOROUGHIFAR, Assistant Professor of Business Technologies – Ph.D., University of Toronto; Carnegie Mellon, 2023–
- JEFFREY GALAK, Associate Professor of Marketing – Ph.D., New York University; Carnegie Mellon, 2009–
- JOHN GASPER, Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008–
- BRENT GLOVER, Associate Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 2011–
- EVELYN XIAO-YUE GONG, Assistant Professor of Operations Management – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–
- DAVID GOYETTE, Associate Teaching Professor of Business Communication and Acting
- MEREDITH GRELLI, Assistant Teaching Professor of Entrepreneurship – MBA, Carnegie Mellon University; Carnegie Mellon, 2022–
- OLIVER HAHN, Assistant Professor of Organizational Behavior and Strategy – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2013–
- DALE HERSHEY, Associate Teaching Professor of Law, Emeritus – LL.B., Harvard Law School; Carnegie Mellon, 1987–
- GEOFFREY HITCH, Associate Teaching Professor of Acting and Business Communication, Emeritus – M.F.A., Carnegie Mellon; Carnegie Mellon, 1992–
- BURTON HOLLIFIELD, Associate Dean of Undergraduate Programs, PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon; Carnegie Mellon, 1998–
- JOHN HOOKER, T. Jerome Holleran University Professor of Business Ethics and Social Responsibility; Professor of Operations Research, Emeritus – Ph.D., Vanderbilt University; University of Tennessee; Carnegie Mellon, 1984–
- YAN HUANG, Associate Professor of Business Technologies – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018–
- RUBAB JAFRY-O'CONNOR, Distinguished Service Professor of Management – Ed.D., University of Pittsburgh; Carnegie Mellon, Carnegie Mellon 2019–
- JIM JEN, Distinguished Service Professor of Entrepreneurship – M.B.A., Stanford University; Carnegie Mellon, 2023–
- ZHAOHUI (ZOEY) JIANG, Assistant Professor of Business Technologies – Ph.D., University of Michigan; Carnegie Mellon, 2020–
- JOSEPH B. KADANE, Leonard J. Savage University Professor of Statistics and Social Sciences, Emeritus – Ph.D., Stanford University; Carnegie Mellon, 1969–
- KARAM KANG, Associate Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2012–
- SHAM KEKRE, Distinguished Service Professor of Operations Management – Ph.D., University of Rochester; Carnegie Mellon, 1984–
- SUNDER KEKRE, Vasantrao Dempo Professor; Professor of Operations Management; Academic Director Executive Education – Ph.D., University of Rochester; Carnegie Mellon, 1984–
- ROBERT KELLEY, Distinguished Service Professor of Organizational Behavior and Theory – Ph.D., Colorado State University; Carnegie Mellon, 1977–
- FATMA KILINC-KARZAN, Associate Professor of Operations Research; Frank A. and Helen E. Risch Faculty Development Professor of Business – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2011–
- MINKYUNG KIM, Assistant Professor of Marketing – Ph.D., Yale University; Carnegie Mellon, 2023–
- TAE WAN KIM, Associate Professor of Business Ethics; Xerox Junior Faculty Chair – Ph.D., University of Pennsylvania; Carnegie Mellon, 2012–
- DAVID KRACKHARDT, Professor of Organizations, H. John Heinz III College and Joint Appointment at Tepper School of Business – Ph.D., University of California, Irvine; Carnegie Mellon, 1991–
- ROBERT E. KRAUT, Herbert A. Simon Professor of Human-Computer Interaction, Emeritus, School of Computer Science and Joint Appointment at Tepper School of Business – Ph.D., Yale University; Carnegie Mellon, 1993–
- LARS-ALEXANDER KUEHN, Associate Professor of Finance – Ph.D., University of British Columbia; Carnegie Mellon, 2008–
- ALEXEY KUSHNIR, Assistant Professor of Economics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2014–
- FINN KYDLAND, The Richard P. Simmons Distinguished Professorship; University Professor of Economics; Emeritus; Nobel Laureate (2004) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1977–
- DAVID L. LAMONT, Associate Teaching Professor; Director, Management Games – M.S.I.A., Carnegie Mellon University; Carnegie Mellon, 1984–
- DEREK LEBEN, Associate Teaching Professor of Business Ethics – Ph.D., Johns Hopkins University; Carnegie Mellon, 2012–
- JUAN RIVERA LEBRON, Assistant Professor of Marketing – M.F.A., University of Idaho; Carnegie Mellon, 2022–
- SUNKEE LEE, Associate Professor of Organizational Theory and Strategy – Ph.D., INSEAD; Carnegie Mellon, 2017–
- REBECCA LESSEM, Associate Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011–
- ANDREW A. LI, Assistant Professor of Operations Research – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2018–
- PIERRE JINGHONG LIANG, Professor of Accounting – Ph.D., University of Florida; Carnegie Mellon, 1998–
- YUCHENG LIANG, Assistant Professor of Accounting – Ph.D., Stanford Graduate School of Business; Carnegie Mellon, 2020–
- ZACHARY CHASE LIPTON, Assistant Professor of Machine Learning and Operations Research School of Computer Science Joint Appointment at Tepper School of Business – Ph.D., University of California, San Diego; Carnegie Mellon, 2018–
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- CRAIG MARKOVITZ, Distinguished Service Professor of Entrepreneurship; Entrepreneur-in-Residence, Swartz Center – MBA, DePaul University; Carnegie Mellon, 2017–
- JOHN H. MATHER, Teaching Professor of Marketing, Emeritus – Ph.D., University of Arizona; Carnegie Mellon, 1992–
- DAVID S. MAWHINNEY, Teaching Professor of Entrepreneurship; Executive Director of the Swartz Center for Entrepreneurship; Executive Director, Donald H. Jones Center for Entrepreneurship – MBA, Carnegie Mellon University; Carnegie Mellon, 2011–
- SIMON MAYER, Assistant Professor of Finance – Ph.D., Erasmus University Rotterdam and Tinbergen Institute; Carnegie Mellon, 2023–
- J. PATRICK MCGINNIS, Distinguished Career Professor of Business Management Communication, Carnegie Mellon-Qatar – M.A., Pittsburg State University; Carnegie Mellon, 1999–
- ROBERT M. MILLER, Richard M. Cyert and Morris DeGroot Professorship in Economics and Statistics; Professor of Economics and Strategy – Ph.D., University of Chicago; Carnegie Mellon, 1982–
- ROBERT T. MONROE, Teaching Professor of Business Technologies; Director, Part-Time Online Hybrid MBA Program – Ph.D., Carnegie Mellon; Carnegie Mellon, 2004–
- ALAN MONTGOMERY, Professor of Marketing; Executive Director, Center for Marketing Technology and Information; Head, Ph.D. Program – Ph.D., University of Chicago; Carnegie Mellon, 1999–
- BENJAMIN MOSELEY, Carnegie Bosch Associate Professor of Operations Research – Ph.D., University of Illinois; Carnegie Mellon, 2018–
- D. CARRINGTON MOTLEY, Assistant Professor of Organization Theory and Entrepreneurship – Ph.D., Stanford University; Carnegie Mellon, 2022–
- TRIDAS MUKHOPADHYAY, Deloitte Consulting Professor of e-Business; Professor of Business Technologies – Ph.D., University of Michigan; Carnegie Mellon, 1986–
- NICHOLAS Z. MULLER, Professor of Economics, Engineering, and Public Policy (joint with the Department of Engineering and Public Policy, College of Engineering; Lester and Judith Lave Development Chair in Economics,

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R. RAVI, Andris A. Zoltners Professor of Business; Professor of Operations Research and Computer Science; Director of Analytics Strategy – Ph.D., Brown University; Carnegie Mellon, 1995–

MAX W. RISCH, Assistant Professor of Accounting – Ph.D., University of Michigan; Carnegie Mellon, 2020–

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CATHERINE SHEA, Assistant Professor of Organizational Behavior and Theory – Ph.D., Duke University; Carnegie Mellon, 2017–

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ALI SHOURIDEH, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–

KARAN SINGH, Assistant Professor of Operations Research – Ph.D., Princeton University; Carnegie Mellon, 2021–

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FALLAW B. SOWELL, Associate Professor of Economics – Ph.D., Duke University; Carnegie Mellon, 1988–

CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979–

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ANTHONY P. STANTON, Teaching Professor of Graphic Media Management, Emeritus – Ph.D., University of Pittsburgh; Carnegie Mellon, 1996–

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ANDRÉ SZTUTMAN, Assistant Professor of Economics – Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2023–

SRIDHAR R. TAYUR, The Ford Distinguished Research Chair; University Professor of Operations Management – Ph.D., Cornell University; Carnegie Mellon, 1991–

CHRISTOPHER I. TELMER, Associate Professor of Financial Economics – Ph.D., Queen's University at Kingston (Canada); Carnegie Mellon, 1992–

MICHAEL A. TRICK, Dean, Carnegie Mellon University, Qatar; Harry B. and James H. Higgins Professor of Operations Research – Ph.D., Georgia Institute of Technology; Carnegie Mellon, 1988–

DAVID E. TUNGATE, Distinguished Service Professor of Law – LL.B., University of Illinois School of Law; Carnegie Mellon, 1991–

WILLEM-JAN VAN HOEVE, Senior Associate Dean for Education, Carnegie Bosch Professor of Operations Research – Ph.D., University of Amsterdam; Carnegie Mellon, 2007–

BETH WALTER, Assistant Teaching Professor of Business Communication – Ph.D., Duquesne University; Carnegie Mellon, 2014–

LAURIE R. WEINGART, Richard M. and Margaret S. Cyert Professor of Organizational Behavior and Theory – Ph.D., Northwestern University; Carnegie Mellon, 1989–

ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012–

ERINA YTSMA, Assistant Professor of Accounting – Ph.D., University of Minnesota; Carnegie Mellon, 1985–

ANITA WILLIAMS WOOLLEY, Associate Dean, Research; Professor of Organizational Behavior and Theory – Ph.D., Harvard University; Carnegie Mellon, 2008–

Courtesy

KATHLEEN CARLEY, Professor of Computation, Organization and Society, Institute for Software Research and by courtesy, Tepper School of Business

KAREN CLAY, Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Stanford University; Carnegie Mellon, 1994–

VINCENT CONITZER, Professor of Computer Science, School of Computer Science, and by courtesy, Tepper School of Business

MARTIN GAYNOR, E.J. Baron University Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Northwestern University; Carnegie Mellon, 1995–

MOR HARCHOL-BALTER, Professor of Computer Science, School of Computer Science, and by courtesy, Tepper School of Business – Ph.D., University of California at Berkeley; Carnegie Mellon, 1996–

AKSHAYA JHA, Assistant Professor of Economics and Public Policy, Heinz College, and by courtesy, Tepper School of Business

DANIEL NAGIN, Teresa and H. John Heinz III University Professor of Public Policy and Statistics, Heinz College and by courtesy, Tepper School of Business

STEPHEN ROEHIG, Teaching Professor of Information Systems, Heinz College, and by courtesy, Tepper School of Business

STEVEN SHREVE, University Professor of Mathematical Sciences; Orion Hoch Professor of Mathematical Sciences, Mellon College of Science, and by courtesy, Tepper School of Business, Emeritus – Ph.D., University of Illinois; Carnegie Mellon, 1977–

RAUL TELANG, Professor of Information Systems, Heinz College, and by courtesy, Tepper School of Business – Ph.D., Carnegie Mellon University;

Visiting Faculty

SUBHAM AKSHAT, Visiting Assistant Professor of Operations Management – Ph.D., University of Maryland; Carnegie Mellon, 2022–

DIANE RULKE, Visiting Assistant Professor of Organizational Behavior and Theory – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2023–

INKI SUL, Visiting Assistant Professor of Operations Management - Ph.D.,
The University of Texas at Dallas;

GAOING ZHANG, Visiting Associate Professor of Accounting - Ph.D.,
Carnegie Mellon University; Carnegie Mellon, 2023-

Adjunct Faculty

SEAN AMMIRATI, Adjunct Professor of Entrepreneurship

STEVEN BOLLINGER, Adjunct Professor of Entrepreneurship

LEONARD CARIC, Adjunct Professor of Entrepreneurship

L. FRANK DEMMLER, Adjunct Professor of Entrepreneurship

CLIFFORD EARLY, Adjunct Professor of Law

JIM FOSTER, Adjunct Professor of Finance

JOSEPH HORNACK, Adjunct Professor of Law

WILLIAM KAIGLER, Adjunct Professor of Entrepreneurship

ADAM PAULISICK, Adjunct Professor of Entrepreneurship

NICK PRETNAR, Adjunct Professor of Economics

JOHN PSARIS, Adjunct Professor of Economics

CARLA RICHARDS, Adjunct Professor of Business Communication

Undergraduate Business Administration Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

70-100 Global Business

Fall and Spring: 9 units

The course is for non-Tepper BA students and provides a comprehensive overview of business, including how enterprises determine goals, strategies and operational tactics in competitive markets and the increasingly global environment. It covers different types of businesses - entrepreneurial and corporate, industries, markets, and economies. Students learn about the role of business in society, the various functional areas that make business work, and how companies develop plans and processes to achieve their goals for customers, shareholders, and employees. The course has special emphasis on providing a broad overview of business to augment students' major area of study for their professional development. Declared Tepper BA students are not eligible to enroll. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-104 Business Leadership Endeavor I

Fall and Spring: 3 units

Business Leadership Endeavor (BLE) is a required 3-mini course sequence (70-104, 70-204, 70-304) offered to undergraduate business students only. BLE 70-104 is the first mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-104 will introduce students to the fundamental building blocks required for their development. Students will learn to develop and improve habits, sharpen personal and professional development skills, and develop meaningful networks. This course uses course material that requires students to pay an additional course fee. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-106 Business Science

Fall: 9 units

This course is only available for Business Majors. The focus on the class is on the three core "lenses" used to study and advance the science and practice of business. We will study: the mathematics of optimization, economics, and the behavior in and of organizations. These are the foundations of the disciplines of finance, accounting, marketing, ..., that follow in the curriculum. Over the course of the semester, we will tackle complex multifaceted business problems. Think of examples like, bike-share and the "share-economy," international trade and supply chain, AI and the impact on work. For each case, we will work to apply the three lenses. A pillar for the semester is that business problems are not siloed in narrow disciplines, we must draw resources from disciplines across the entire university. The second pillar of our class is solving all problems - across all of society - requires your understanding of business science. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-110 Business Computing

Intermittent: 9 units

Students will learn how individuals and organizations use computing technologies to support and improve their businesses. At an individual level, students will build their skills with Microsoft Excel and other personal productivity tools. At an organizational level, the class looks at ways in which businesses of all sizes and types leverage computing technologies to run their businesses more efficiently, make better business decisions, and create new business opportunities. This course is reserved for first-year Business students; others may enroll by special permission from the UBA office only.

70-122 Introduction to Accounting

Fall and Spring: 9 units

This course provides the knowledge and skills necessary for the student to understand financial statements and financial records and to make use of the information for management and investment decisions. Topics include: an overview of financial statements and business decisions; the balance sheet, the income statement, and the cash flow statement; sales revenue, receivables, and cash; cost of goods sold and inventory; long-lived assets and depreciation, and amortization; current and long-term liabilities; owners' equity; investments in other corporations; an introduction to financial statement analysis and international issues dealing with financial statements. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-204 Business Leadership Endeavor II

Fall and Spring: 3 units

Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students only. BLE 70-204 is the second mini of the BLE course sequence. Each previous mini will serve as a pre-requisite for the next in sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-204 will help students assemble their fundamental building blocks in a way that supports their continued development.

The course will continue to emphasize the importance of strong habits, meaningful networks, and ongoing skill development. Students will begin to connect this development with personal and professional goals. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-105 or 70-104

70-207 Probability and Statistics for Business Applications

Fall and Spring: 9 units

Elementary ideas in probability, statistics, and data analysis are presented in the context of their importance to modern business management.

This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/70207/probability-and-statistics-for-business> (<http://tepper.cmu.edu/prospective-students/course-page/70207/probability-and-statistics-for-business/>)

70-208 Regression Analysis

Fall and Spring: 9 units

This class focuses on the statistical analysis of the relationship between two or more random variables. In particular, we examine the estimation of the conditional mean of the dependent variable as a function of independent variables using linear regression. We draw on statistical theory to determine the precision of our estimates and to conduct inference about the population, and we examine a number of applications to business, finance, and economics throughout the course. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 36-218 or 36-200 or 36-201 or 36-247 or 70-207 or 36-207 or 36-220

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/70208/regression-analysis> (<http://tepper.cmu.edu/prospective-students/course-page/70208/regression-analysis/>)

70-246 Innovation & Entrepreneurial Mindset

Intermittent: 6 units

This course is designed to introduce students to the theory and frameworks used to develop and implement innovative solutions to societal and entrepreneurial problems. The curriculum incorporates the latest on innovative behavioral traits and frameworks with a highly experiential format to expose undergraduate students to out of the box thinking. For example, the instructor would use the lecture section of the class to explain the behavioral techniques that lead to innovative solutions (based on the Innovator's DNA by Clayton Christensen). Teams of 3-6 students each would then examine a problem and be asked to generate 3 potential solutions and a proposed solution, using the techniques presented. Volunteers from the local Carnegie Mellon and entrepreneurial community will serve as mentors and judges, thereby providing a real world learning and networking experience. Ultimately, the best solution will be selected, using a shark tank format. While the selection of a winning solution will be fun for the class, the students will be graded on their having demonstrated the theory and techniques presented in class. Each week will address a new and important topic related to the innovative and entrepreneurial mindset. Weekly format will include one day of lecture and one day of application of the theory introduced in a fun and competitive format. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-257 Optimization for Business

Fall and Spring: 9 units

This course provides a mathematical foundation for the application of optimization techniques to business problems, as well as the practical implementation of these methods. Mathematical optimization techniques have been applied for decades in the context of logistics, supply chain management, and strategic planning, with great success. In this course, the most important methods and techniques underlying mathematical optimization are studied. These include linear programming, integer programming, and nonlinear programming as basic mathematical methodologies. Based on these, we also consider methodologies for particular problem classes such as network models and traveling salesman problems. During the course we will emphasize mathematical modeling, that is, creating a mathematical description that reflects a given practical problem described in words. Motivated by these mathematical models, we then discuss the necessary mathematical techniques for finding optimal solutions. Lastly, we consider the solution of these problems using optimization software, i.e., we represent the mathematical models in Excel and use Excel Solver to compute an optimal solution. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 21-256 or 21-259 or 21-254

70-258 Developing Blockchain Use Case

All Semesters: 6 units

Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. <http://tinyurl.com/cmucoincourse> (<http://tinyurl.com/cmucoincourse/>) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-304 Business Leadership Endeavor III

Fall and Spring: 3 units

Business Leadership Endeavor (BLE) is a required 3-mini course sequence offered to undergraduate business students. BLE 70-305 is the third mini of the BLE course sequence. BLE introduces students to their leadership journey via four development frameworks: student development, personal development, professional development, and community development. BLE 70-305 will continue to build strong personal and professional skills as students get closer to their professional endeavors. Students will be applying learned skills in and out of the classroom and will begin to see how the assembled skills are beneficial to themselves and others. This course will emphasize the importance of continued broad growth and lifelong learning. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-204 or 70-205

70-311 Organizational Behavior

Fall and Spring: 9 units

This course examines the factors which influence individual, group and firm behavior in the context of the workplace. Topics covered include perception, group behavior, decision making, motivation, leadership and organizational design and change. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107) or 76-245 or 76-331 or 76-347 or 76-327 or 76-102

70-318 Managing Effective Work Teams

Intermittent: 9 units

Over the past decade, managers have greatly expanded their use of teams to accomplish a wide variety of organizational objectives. Teams have emerged as a favorite work arrangement for such ongoing activities as developing new products, providing professional services, and starting new businesses. Temporary groups are frequently assembled for a multitude of purposes, such as making difficult decisions, solving cross-functional problems, generating ideas, or performing unique tasks. Indeed, groups and teams can be found at every level of the organization, from production crews on the shop floor to top management teams in the executive suite. Moreover, advances in communication technology have created the potential for people who are dispersed across the globe to collaborate virtually, creating many new opportunities and challenges for leaders of such teams. Teams are not a panacea, however. Even as they become a way of life in many organizations, widespread myths and misconceptions about teams often stand in the way of effective teamwork. At their worst, teams sometimes create more problems than they solve. The core content of the course is a series of team and group exercises, case analyses, and readings. The exercises are framed and analyzed in terms of readings, lecture, and in-depth class discussions. Much of the learning that occurs in the course will involve exercises, simulations, and cases that draw on students' current experiences in the class as well as their previous experiences in teams and organizations outside of this class. Prerequisite: 70-311

70-321 Negotiation and Conflict Resolution

Intermittent: 9 units

This course will complement the technical and diagnostic skills you have learned in other courses. A basic premise of the course is that, while you will need analytical skills to discover optimal solutions to problems, you will also need a broad array of negotiation skills to implement these solutions and make sure that they are truly effective. Your long-term effectiveness - both in your professional and personal life - is likely to depend on your negotiating abilities. This course will give you the opportunity to develop these skills experientially and to understand the analytical frameworks that underlie negotiations. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

70-324 Emotions and Decision Making Within and Outside of Organizations

Intermittent: 9 units

In this seminar-style course, we will examine the role of emotions within and outside of organizations. Topics related to the course are likely to include theories of emotion, positive and negative emotions, emotions and decision making, emotion in teams, emotions in performance, justice violations, workplace attitudes, and revenge. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-332 Business, Society and Ethics

Fall and Spring: 9 units

What sorts of ethical obligations do businesses have towards their customers, employees, and the public? This course will explore ethical challenges faced by modern corporations, and frameworks which can be used to develop responsible corporate policy. The course is divided into four main units: (1) autonomy and consent, (2) the scope and locus of corporate responsibility, (3) fair treatment and outcomes, (4) the limits of labor and commodification. This course may use copyrighted material. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 76-102 or 76-101 or (76-107 and 76-106) or (76-106 and 76-108) or (76-108 and 76-107)

70-334 Ethics of Emerging Technologies

Intermittent: 9 units

New technologies transform the ways that companies deliver value to consumers, but they also raise important ethical challenges. We will examine these challenges with the goal of developing strong normative arguments for corporate policies. Topics covered include: online data collection, media, and marketing; metaverse and virtual reality platforms; autonomous objects; genetic screening and engineering; neural screening and engineering; narrow and general artificial intelligence. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 76-101 or 76-102 or 70-332 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-337 Business of Blockchain

Intermittent: 9 units

Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different "tokenomics" models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 73-102 Min. grade C and 73-103 Min. grade C

70-339 FinTech

Intermittent: 9 units

The financial services industry is a leader in the use of information technology. Firms in banking, securities, investments, insurance and financial marketplaces are among the most information intensive and innovative users of technology. The course will examine the role and potential of technology in this industry. The course begins with a description of the financial markets, specifically equity, foreign exchange, and derivatives, and the systems that enable them. It considers exchanges, ECNs, ATS's Order Management Systems, Straight through Processing, Fix Protocol, and post trading clearance and settlement. It covers the design, evaluation and execution of popular trading strategies that are used by professionals in the various markets. There is increasing interest, in particular, on systematic trading strategies and execution systems because of their scalability and transparency. The course covers both Algorithmic and High Frequency Trading and analyzes issues regarding latency, scalability, and reliability. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisite: 70-391

70-340 Business Communications

Fall and Spring: 9 units

Business Communications develops and sharpens your written, oral, and interpersonal communication, introducing you to common forms of professional writing and speaking in specific business situations. The course explores crucial rhetorical issues that impact your ability to communicate and achieve your objectives as a business leader. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-341 Team Dynamics and Leadership

Intermittent: 9 units

Organizations have greatly expanded their use of teams to accomplish a wide variety of objectives. Teams develop new products, provide professional services, and start new businesses. Temporary teams are frequently assembled to make difficult decisions, solve cross-functional problems, and generate new ideas. Advances in communication technology allow people dispersed across the globe to collaborate virtually, creating many new opportunities and challenges for leaders of such teams. This course will provide you the knowledge and skills to communicate in teams and to lead them effectively. It will help you better communicate in and lead teams and organizations. You will learn both effective leadership practices as well as how to avoid common leadership mistakes. Our readings reflect both the scientific and practice literatures and class exercises, cases, and projects provide the opportunity to apply what you learn. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 36-207 or 36-220 or 36-247 or 36-225 or 70-207 or 36-217 or 36-201 or 36-200

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/70341/organizational-communication> (<http://tepper.cmu.edu/prospective-students/course-page/70341/organizational-communication/>)

70-342 Managing Across Cultures

Intermittent: 9 units

This course is designed for students who expect to do business in other countries or work with people from other cultures. It provides an intellectual framework for understanding other cultures (and eventually one's own), as well as detailed studies of particular countries. It discusses how culture defines organizations, contracts, personal relationships, attitudes toward authority, time and space, ethics, wealth, and subcultures, and how these affect business. Student teams study a culture of their choice and make presentations, based on interviews and literature research. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 76-101 or 76-102 or (76-108 and 76-107) or (76-106 and 76-107) or (76-106 and 76-108)

70-344 Internet Ethics

Intermittent: 3 units

The use and abuse of social media and other online platforms has become a major global issue. This course provides a conceptual framework for analyzing some of the ethical controversies these practices raise. Controversial practices include collection and selling of personal data, promotion of rumor and misinformation, cyberbullying, manipulation of social media newsfeeds, and electronic surveillance, as well as efforts by Internet platforms to curtail these activities. Student teams will analyze and ethically evaluate the Internet activities of a platform or company of their choice and present their findings to the class.

70-345 Business Presentations

Fall and Spring: 9 units

In this course, students prepare, present, discuss, and critique different oral presentations currently practiced in business. Topics include developing your presence in a professional setting; projecting credibility, professionalism, and authority; and planning presentations to influence business audiences. Assignments and cases will cover informative and persuasive presentations, which will vary from term to term and may include talks such as product pitches, team-driven strategic plans, and state-of-the-company addresses. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 73-270 or 70-340

70-348 Cross-Cultural Business Communications

Intermittent: 9 units

This course considers cultural behaviors, assumptions, values, and conflicts surrounding business communication across cultures. It will begin with an evolving definition of "culture" and consider several cultural variables that may affect communicative success (i.e. collectivist/individualist cultures, high-/low-context languages, monochronic/polychronic cultures). Students will research and present findings on the characteristics of specific cultures. They will prepare business documents and presentations that build on the knowledge and skills acquired in 70-340, Business Communication, and reflect new sensitivities to the needs of specific cross-cultural audiences. This course is offered only at the Carnegie Mellon-Qatar campus. Prerequisites: 76-270 or 70-340 or 15-221

70-350 Acting for Business

Intermittent: 9 units

Perception may or may not be Reality. But Perception is, in fact, what influences people. This experiential communications course focuses on how you as a Leader can choose to more effectively express yourself and amp; influence others using practical, hands-on tools from Acting in professional, live Theatre. You will choose to effectively influence your Listeners' perception of you through the use of: "Action"; Assertiveness, Confidence and amp; Expressiveness (ACE); the Visual, Aural and amp; Temporal Communication Tools; and the incorporation of The Seven Steps Of Effective Influence (or core competencies). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-352 Business Acting

Spring: 3 units

This is a one-week course that is offered only at CMU in Qatar. This course provides a uniquely broadening educational experience for business students through an exploration and amp; understanding of the process of Acting and amp; the unique performer/audience relationship. Using techniques of Acting, the course will concern itself with: a new self-awareness and amp; greater confidence in public communication; the expansion and amp; diversification of one's range of personal expression; methods to more effectively shape a public performance and amp; of empowering the student to put his/her best Self forward when in contact with an audience; and amp; a re-investment in passion.

70-353 Financial Regulation in the Digital Age

Intermittent: 9 units

The course will address the foundations of regulation (why regulate?) from various perspectives within the context of a market economy, highlighting the sources of market failure (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as taxes and fees, disclosure, price regulation, guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? Are our markets rigged? How can regulators enhance the predictability and credibility of their policies? How costly were government guarantees during the financial crisis? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? How does the Dodd-Frank Act promote financial stability? What basic aspects of the financial crisis did Dodd-Frank not address? (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: (21-120 or 21-112) and (21-268 or 21-269 or 21-256 or 21-259) and 73-230

70-354 Communication: Social Media in Action

Intermittent: 6 units

Building upon what you already learned in Business Communications, this course will amplify your ability to successfully work in teams to produce social media content, collaborate via online mediums, and build online communication skills through development of an effective online presence. You will create and deliver social media content for your chosen organizations in this online space. This is a differentiator for you; after this course, you will be able to go into an interview confidently and share your team experience helping the organization build a successful social media presence. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-340 or 73-270

70-364 Business Law

Intermittent: 6 units

This course covers the fundamental principles of law that govern business affairs in the United States, with some reference to the laws of other countries. The topics include constitutional sources of business law, administrative agencies, contract law, agency, employment, business forms (corporations, partnerships, limited partnerships, limited liability companies, agency arrangements, franchises), intellectual property and unfair competition, legal liability of professionals, international trade and antitrust. Prerequisites: 70-340 or 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-107 and 76-108)

70-365 International Trade and International Law

Intermittent: 9 units

The course discusses the international legal system and laws that affect international trade. It covers the Foreign Corrupt Practices Act, treaties and concessions, shipping and customs, appointment of foreign sales agents, resolution of trade disputes, international mergers and joint ventures, international competition law, UN sales convention, international trade organizations (IMF, WTO, World Bank, etc.), risk insurance, cultural factors, international E-Commerce and intellectual property. Prerequisites: 73-102 or 73-100

70-366 Intellectual Property and E-Commerce

Intermittent: 6 units

The course is intended to instruct students on the creation of the Internet and the World Wide Web, including the creation of the Domain Naming System. The course will provide an understanding of how the Web operates (from its creation to the present), how the laws of various countries interact with the Web; how issues of privacy are addressed and the role of private parties and government in monitoring privacy. The course will examine how intellectual property is created and protected; who owns the property; and the role of ownership of the intellectual property interacts with antitrust laws. The course examines how contracts are formed and administered on the Web by entities created to minimize taxes and personal liability risks for the owners/shareholders of those entities. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-106 and 76-108) or (76-108 and 76-107)

70-371 Operations Management

Fall and Spring: 9 units

This course is an introduction to production and operations management that covers both manufacturing and services. It deals with strategic issues (design of flexible supply), planning issues (capacity management), and operational issues (inventory management and information). The linkage between strategy and tactics will be emphasized. The students will learn concepts and tools that will help them to manage from the "boardroom" to the "toolroom." This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 36-220 or 36-200 or 36-207 or 36-225 or 36-247 or 70-207 or 36-218 or 36-201

70-373 Sustainable Operations

Intermittent: 9 units

This course explores and defines sustainability in general, and sustainable operations in particular. The course investigates how companies can evaluate and implement sustainability measures, and different motivations for firms to engage or invest in sustainable efforts. Sustainable operations is approached from the value chain perspective, by identifying opportunities for sustainable actions and policies at different phases in the product life cycle. These phases range from research and development to the point where products are discarded by the consumer, for potential reuse or recycling. Quantitative operations models and techniques will be used to analyze and evaluate the viability of these sustainable opportunities. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-106 or 70-100

70-374 Data Mining & Business Analytics

Intermittent: 9 units

Interest in big data analytics has skyrocketed recently. The recent explosion in large-scale high-resolution data enables managers to ask and answer questions regarding businesses and consumers at a whole new level. Managers are faced with data about businesses and consumers that are growing faster than they can be utilized. Data mining enables business to extract useful consumer behavior and preferences from seemingly tremendous and unorganized data, which then can be utilized for data-driven decision-making and competitive advantage. Applications can be found in e-commerce, sales, marketing, finance, operations, etc. In this hands-on introductory class, you will learn the basic concepts and techniques of data mining in addition to when and how they can be applied to improve many aspects of business and consumers' welfare. Throughout the course, we will use R, a powerful open-source statistical language and one of the main tools in data mining and business analytics, fast becoming a mainstream tool. With this tool, you will learn about variety of exploratory and predictive data analytics techniques such as Naïve Bayes classifier, nearest neighbor approaches, decision trees, clustering algorithms, etc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-208 or 36-208 or 36-202 or 36-225

70-376 Energy Systems

Fall: 9 units

This course will provide students with an understanding of the systems and markets that provide energy to businesses and consumers. Students will be introduced to the sources and uses of energy, and how they have evolved and the possible paths over which they may evolve in the next decades. The course places an emphasis on electric energy, the single largest energy source in many industrial economies, but also covers natural gas, oil, and selected other primary energy sources. Students will learn the energy flows in the USA and the world, as well as the business-relevant characteristics of the engineered systems that provide the energy in various forms. Both traditional and emerging energy sources will be discussed, and students will understand the difference between an energy carrier and an energy source. We will also discuss some of the issues that arise without proper management of the physical risks of energy systems. Students will learn some of the history of electric power regulation and the inconsistent subsidy structures that have provided opportunities and challenges for energy companies and investors, including discussion of how emissions restrictions affect fuel, engineering, investment, and project finance choices. The history of electric power markets will be discussed, with an eye to examining the opportunities that market changes create for business.

70-381 Marketing I

Fall and Spring: 9 units

An introduction to the nature and fundamentals of marketing and consumer behavior. Topics include an analysis of the economic and psychological factors influencing buyer behavior, marketing research, market segmentation, and the development of marketing programs (new product, price, advertising and distribution decisions). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 76-102 or 76-101 or (76-106 and 76-107) or (76-108 and 76-106) or (76-107 and 76-108)

70-385 Consumer Behavior

Intermittent: 9 units

Marketing, in particular, begins and ends with the consumer from determining consumer needs to ensuring customer satisfaction. In this course, we will explore the most recent scientific research in marketing, psychology, and behavioral economics on judgment and decision-making. We will develop your ability to understand and influence what people want, how people decide what and when to buy, and whether people will be satisfied or dissatisfied with their decisions. These psychological insights are particularly useful for marketing strategy, brand positioning, and marketing communication decisions, but also yield insight into common biases in judgment and decision making, beyond marketing, to which you would otherwise fall prey. Why people are willing to drive across town to save \$5 on a tank of gasoline, for example, when they would not drive a minute to save \$5 on a refrigerator. We will discuss some of these applications in class. In addition, we will examine the methodology of market research (specific to consumer behavior) to build the tools you will need to interpret and base decisions on it. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-381

70-386 Applied Behavioral Decision Making For Business

Intermittent: 6 units

This course is intended to give future managers, consultants, and policy makers an introduction to the insights and applications of behavioral decision making. Behavioral decision making is the interdisciplinary study of how people make decisions. It draws together research from psychology, economics, political science, and management, among other fields. Topics include heuristics and biases in inference and prediction, risk perceptions and attitudes, and the roles of group and emotional processes in decision making. In this course we will address applications of these findings from the various behavioral sciences to the study of business. This course is offered only at the Carnegie Mellon-Qatar campus. Prerequisites: (70-207 or 36-201 or 36-200) and 73-100

70-387 Strategy for High-Tech Products and Services

Intermittent: 9 units

This course will focus on the strategies of technology-based products and services. We will examine how technology products/services differ from non-technology-based products and how the unique attributes of high-technology products/services influence the marketing strategies and tactics of those products. We will cover issues such as pricing of technology products/services including versioning, bundling and dynamic pricing; the impact of network effects within product markets; competition in technology-focused product arenas; the design, launch and governance of platform markets. Examples of technology-intensive industries that we will discuss are computer hardware and software, media and entertainment, telecommunications, e-commerce, and the sharing economy. Students explore the unique economic circumstances facing firms in these industries and identify strategies that enable firms to succeed given these circumstances. This course is ideal for students who want to pursue a career as a product manager for a technology company. This course helps students understand the unique economic characteristics seen in today's technology-intensive markets and how they impact the strategic interactions among firms and consumers. In order for students to understand how firms strategically interact in technology-intensive industries this course will use a combination of simple but rigorous analytical models, emerging theories, and formal case studies.

70-388 Islamic Finance

Intermittent: 9 units

This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

70-389 Design Thinking for Business: Creative Solutions for Complex Problems

Intermittent: 9 units

In today's rapidly evolving world, businesses constantly seek innovative solutions to complex problems. Design Thinking has emerged as a powerful methodology to address these challenges by fostering creativity, empathy, experience, and collaboration. This course introduces the principles, methods, and tools of Design Thinking and explores a powerful array of critical techniques and frameworks from problem framing and creative ideation, to digital prototyping and user testing. We will use Figma to enhance the Design Thinking journey and learn how to work together in real-time in the modern collaborative environment. Through a combination of theoretical knowledge, real-world case studies, and hands-on activities, we will engage in a dynamic learning journey and develop the mindset and skills necessary to tackle challenges and create innovative solutions to drive meaningful change. By the end of this course, students will be equipped to lead innovation efforts, create experience-centric solutions, and drive meaningful change in organizations and communities.

70-391 Finance

Fall and Spring: 9 units

Firms create value by making good investment decisions. Finance is the field of management science tasked with making this happen. It is a set of tools with which firms identify good investments and decide how to pay for them. Paying for them ultimately involves getting money from households. Therefore, finance also describes the investment decisions of households and the resulting allocation of the economy's resources across firms and time. This course is the introductory finance course in the undergraduate business program. The main topics covered in the course are Financial Markets, Net Present Value, The Objective of the Firm, Discounted Cash Flow, Portfolio Theory and the Cost of Capital, The Efficient Markets Hypothesis, The Capital Structure of the Firm, and Business Valuation. Time permitting, the course will also provide an introduction to option markets and derivative securities. Upon completing the course a student will be able to consider a large and complex business problem, make some assumptions, structure the firms' cash flows in a spreadsheet, calculate the value of different solutions to the problem, and make a decision. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: (73-100 or 73-102) and (36-200 or 70-207 or 36-218 or 36-201 or 36-217 or 36-207 or 36-225)

70-395 Funding Entrepreneurial Ventures

Intermittent: 9 units

So you want to do a startup and you know that you need funding. There are multiple ways to fund a new venture: bootstrapping, economic development, angels, venture capitalists. The question is what are these funders looking for in an early stage investment? What is important to them? How do they decide which companies to invest in and which not? This class looks at funding from the funder's point of view and provides the student with a framework of the investment process: investment criteria, sourcing, selection, due diligence, deal structure, valuation, post investment involvement. Real companies seeking funding are used for the final project in which students will be expected, as investment teams, to make investment decisions and convince their fellow investors (the class) to join them (or not). This is a highly interactive and project class. There will be multiple guest speakers. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-398 International Finance

Intermittent: 9 units

International Finance is an elective course designed to give students the opportunity to analyze real-world problems in international capital markets. Topics covered include: exchange rate determination and quoting, international parity relations, foreign exchange hedging strategies using forwards and options, foreign exchange exposure management, international bond market, currency swap market, global equity market, international portfolio risk assessment and performance measurement. Students develop problem solving and communication skills with presentations and critical discussions of case studies. Prerequisite: 70-391

70-401 Management Game

Fall and Spring: 12 units

This course is designed to integrate the managerial concepts and techniques studied earlier in the curriculum and to focus on elements of organizational structure and behavior. Student teams assume the role of top management of firms competing in an international economy simulated by the Carnegie Mellon University Management Game. Each team is responsible to a Board of Directors comprised of alumni of the MBA program and business masters students. Emphasis is placed on the development and implementation of sound organizational decision structures as well as the formulation of effective competitive strategies. The course is reserved for senior-year business majors and additional majors. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-391 and 70-381 and 70-371 and 70-122

70-409 Innovation and Entrepreneurship in Emerging Markets

Intermittent: 9 units

This course focuses on the role that innovation-driven entrepreneurship and market-creating innovation play in the development of economies in emerging markets. The course will explore the potential economic development opportunities brought forward by market-creation innovations in emerging markets and will seek to understand the unique challenges and opportunities of innovation which face entrepreneurs in emerging markets.

70-412 Advanced Business Communications: Power, Persuasion, and Problem-solving

All Semesters: 9 units

Challenges such as communicating leadership and expertise to a newly formed team, receiving unclear expectations, limited time to complete a complex problem, persuading a reluctant colleague, showcasing yourself in a crucial performance review all occur in business. This advanced course digs deeper into how leaders and successful professionals navigate the complex workplace of surprise, ambiguity, crisis, and diversity. You'll explore varied, often high-stakes workplace scenarios to build your persuasive ability, linguistic skill, communicative flexibility, agility, and confidence.

Prerequisites: (70-345 and 70-340) or 73-270

70-415 Introduction to Entrepreneurship

Fall and Spring: 9 units

This course is an introductory course designed to provide an overview of entrepreneurship, develop an entrepreneurial frame of mind and learn the fundamentals of lean startup development. Students, Sophomore year or higher, interested in founding or contributing to a start-up venture, regardless of areas of discipline (engineering, design, business, computer science, music, drama, and more), are welcome. Students can expect to gain a basic understanding of functional areas such as customer discovery, sales, business planning, risk management, venture funding, and more. This class also features "The Sprint: An Entrepreneurship Competition," which affords the students the opportunity to gain experience selling their choice of product in a real-world and competitive environment. The class is a discussion- and project-based class. Class sections feature either a combination of lectures, class discussions, and activities or applied workshops in small groups. Students will be learning a mental framework for evaluating and developing any startup and then applying said framework and techniques to analyze and execute real-world business opportunities. Interdisciplinary teams will generate ideas and explore their potential as viable businesses. Numerous student teams have completed this class with real-world opportunities. Guest speakers, case studies, and exercises will also be integrated. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course. Students enrolled in the course will be required to pay the University the associated additional course materials fee for the third-party course material provided (\$13 to \$75)

70-416 New Venture Creation

Intermittent: 9 units

This course exposes students to the nuances of financing new ventures, getting them started legally and marketing their products or services. Students pull together all the ideas and information from different functional aspects of their projects into coherent and persuasive mini-business plans that serve as roadmaps for building their businesses; and useful instruments to find sufficient financing for the new ventures, so that they can convince the outside world that these opportunities are viable, with substantial potential for success. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-421 Min. grade C or 70-420 Min. grade C or 70-425 or 70-414 Min. grade C or 15-390 or 70-415 Min. grade C

70-422 Managerial Accounting

Intermittent: 9 units

The purpose of this course is to prepare students to make sensible business decisions using accounting information. An essential topic in the course is the measurement and allocation of costs to assist decision making in organizations. The course covers standard topics in cost accounting, such as cost behavior and relevant costs, and connect these to broader issues in microeconomics, decision theory, corporate finance, and operations management. Classes contain a mixture of conventional lectures, problem solving, business cases, and simulations. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-122 and (36-201 or 36-200 or 36-207 or 70-207)

70-423 Technology-Based Entrepreneurship

Spring: 9 units

This course is offered only at Carnegie Mellon's campus in Qatar. This course is designed as an introduction to entrepreneurship and basic business concepts for engineering and science students. There are no prerequisites. Students learn basic business concepts, business models, entrepreneurial thinking, idea generation, opportunity recognition, and the basics of accounting, marketing and strategy development. There is no final examination. Instead, students, working in teams, generate an original idea for a startup business and prepare a business plan and an investor presentation, which sets forth the basic strategies, business models and evaluates the opportunity afforded by their original idea. This course also is consistent with the broad mission of Carnegie Mellon University in Qatar's entrepreneurship program, which is described below. The broad mission of the entrepreneurship program at Carnegie Mellon University in Qatar is three-pronged: a.To encourage and develop entrepreneurial and innovative thinking in a business setting, whether or not it is a startup company; b.To obtain the basic skills to start a new venture; c.To stimulate self-evaluation for life direction.

70-424 Corporate Financial and Sustainability Reporting

Intermittent: 9 units

This course is designed to strengthen your ability to understand and use both financial and sustainability data reported by corporations. For the past five centuries, massive and rich financial data has been generated and intensively used to aid investment decisions in capital markets and business strategies by corporations. More recently, the realm of financial reporting has been significantly augmented along the new dimension of sustainability reporting due to the rapidly growing trend of sustainability-oriented investing and investors' demand for sustainability-related data. The course is aimed at anyone whose career might involve working with financial and sustainability data and should be especially useful for those interested in investing, banking, and consulting careers. Throughout the semester, we will discuss the regulatory and corporate environments that govern the generating process of financial and sustainability data and how understanding such data-generating process helps with drawing implications from the financial and sustainability data about corporate valuations, business strategies, etc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-122

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/70424/corporate-financial-reporting> (<http://tepper.cmu.edu/prospective-students/course-page/70424/corporate-financial-reporting/>)

70-427 Modern Banks: Strategy and Regulation

Intermittent: 9 units

What is the main role that banks play in the economy? Are banks safe and trustworthy? What are the main business areas of a modern full service bank and how does it make profit in each area? What are the main risks that they face and how do they manage those risks? How can the public assess the risks a bank faces and measure its performance? Does the regulation governing banking address these risks effectively? The main goal of this course is to examine these and related questions by focusing on the analysis of banks' financial reports. Students will learn how accounting and disclosure rules for financial instruments and institutions convey detailed information that is useful to evaluate their risks and performance. Potential limitations of the current financial reporting requirements facing banks will also be discussed. The course covers crucial topics in modern banking strategy and regulation such as interest rate risk, provision on loan losses, fair value accounting for financial instruments, repos, securitization, capital requirements, and derivative and hedge accounting. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-391 and 70-122

70-428 Financial Statement Analysis

Intermittent: 9 units

This course is about fundamental analysis using financial statements. We develop and apply technologies for understanding and identifying firm activities that generate shareholder value and for developing valuation benchmarks. The ultimate goal of such analysis is to aid the security valuation and risk analysis exercises. This course is intended to help students establish a good foundation and introduce students the basics of equity and debt analysis techniques. Taking Finance (70-391) before this course is recommended, though not a formal prerequisite. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-122

70-429 Accounting for Financial Institutions

Fall: 9 units

The banking sector is important because it drives the financial growth of an economy. This sector accepts deposits from the public and issues loans, and thus the banking sector expands in response to positive changes in retail, corporate and government business demand. Similarly, if a slowdown occurs this results in a reduction in demand for banking sector services. As a result, the important starting point for a financial analyst, who wants to assess current and future economic growth, are the financial statements of banks and the information they contain. To extract this information, however, requires being able to read and interpret the financial statements of a bank. These statements are very different from reading traditional corporate financial statements. As a result, the first objective of this course is to learn how to read financial statements generated from the banking sector including how to interpret and evaluate these statements. The banking sector in Qatar is unique because it has two important and separate subsectors and #8212;- Islamic and conventional banking. Each of these subsectors have a different banking business model which in turn generate differences in their financial statements. As a result a second important objective for this course is to learn how to read and evaluate the financial statements from each of these subsectors. Prerequisite: 70-122

70-430 International Management

Intermittent: 9 units

This course uses the case method to examine the strategic and operational issues in management practice and decision-making that are important in operating a business that spans national borders. Topics include political and economic risk assessment, technology transfer, cultural analysis, negotiation, social responsibility, organization structure, supply chain management and trends in foreign direct investment and their impact on developing strategies for entering and becoming successful in international markets.

70-437 Strategic Management and Innovation

Intermittent: 9 units

This course focuses on how organizations deliver value in changing business environments, using analytical techniques to evaluate business situations and develop strategies that improve organizational performance. By focusing on the organizational perspective, you will develop practical skills in evaluating and designing ways for firms to achieve key strategic outcomes like growth and innovation, which determine the firm's chances of success in dynamic environments. This course is particularly useful if you are interested in careers such as consulting, business development, investment banking, private equity, entrepreneurship, or simply want a better understanding of how their firm can develop a more innovative outlook. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-311

70-438 Commercialization and Innovation

Intermittent: 9 units

The course is targeted at entrepreneurs and innovators who are interested in introducing innovations to the marketplace through start-up, emerging and established organizations. Class participants will learn how to evaluate, develop and implement opportunities for innovation, using an emergent or iterative approach (the lean methodology). Students will also learn a variety of methodologies to identify opportunities for innovation including how to identify unserved customers, identifying what jobs customers need to do, and how to incorporate innovations originating from end users, suppliers, materials manufacturers, and other entities outside the firm. Students will learn how to develop a Business Model, identify a Minimum Viable Product, and a Market Entry Point. The course is divided into two parts. In the first half students will be exposed to theories and strategies of innovation through readings and case studies. In the second half students will identify and develop their own product concept utilizing concepts developed in the first part of the course, and step-by-step develop their business model, organizational plan, strategic partners, marketing message, sales plan, and financing strategy. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: (73-102 or 73-100) and (70-425 or 70-415 or 15-390 or 70-420 or 70-421 or 70-414)

70-439 Applied Data Science for Business

Intermittent: 9 units

The objective of this project class is to expose students to cutting-edge data science tools applied to a real-world problem. This project course fulfills several academic goals, by applying business analytics and leadership to an actual industrial application. These include: Team management: Learn how to interact and engage with your team members, set goals, and manage the project. Leadership: The project contains different elements, such as coding, writing, and presenting, which allows students to take ownership and lead that part of the project. Analytics: The project contains several analytical components including data analysis and predictive modeling. Product Management: Learn how data and analytics can bring value to a new product.

70-440 Corporate Strategy

Intermittent: 9 units

This course is designed to provide the student with a general management perspective and an understanding of the total business enterprise. It builds upon previous course work in functional areas and provides insights and analytical tools which a general manager should have in order to plan and implement successful business strategy. The student will analyze complex business problems and formulate realistic strategic solutions. Emphasis is placed on the practical application of business theory by the student in their business career.

70-443 Digital Marketing and Social Media Strategy

Intermittent: 9 units

This course explores issues related to digital and social media marketing. This is a hands-on class where students utilize real world data. Specifically, we study the following topics: (a) Search Engine and Sponsored Search Optimization: how search engines, keyword auctions, retargeting, mobile marketing, social network marketing and search engine marketing work, and how to optimize pay per click advertisement efforts. (b) Econo-Mining: how firms are getting or can get useful information from user generated content using text mining and opinion mining capabilities to drive their product development, placement, and advertisement decisions. (c) Social Media/Viral Marketing: how to design a social media marketing campaign; the key ingredients that make such campaigns successful; how to run a campaign for a viral product; measuring the success of a social media campaign (d) Wisdom of the Crowds: how to design crowdsourcing contests; what and how to crowdsource; prediction markets and how to design them for success and the kinds of questions are best suited for prediction markets. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-447 Client Consulting Project: Strategic Management of the Enterprise

Intermittent: 12 units

This is a project course for senior business majors offered in partnership with real-world client companies; students must apply for the course and enrollment is by special permission. Students will learn about the challenges of the multi-dimensional and complex issues faced by managers, including learning the concepts and skills to handle ambiguity, perform a persuasive data analysis, and communicate the findings effectively. Students will develop a deeper understanding of how organizations can co-ordinate and leverage synergies across a range of disciplines by effective deployment of technologies and organizational structures and processes. Teams will have an opportunity to work with clients on a wide mix of problems spanning multiple functions, including strategy, operations, technology and marketing. Specifically, teams will address issues such as big data, mobile application strategies, supply chain, digital media, complexity management, health care delivery models and healthcare marketing strategy. Regular meetings with the instructor will be scheduled to guide teams during client engagement and co-ordinate with the executives at their client company. The deliverables will be in the form of a report/prototype and a final presentation to the client's executive team. No classes to attend, but weekly team meetings with times to be determined. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-381 and 70-371 and 70-391 and 70-311 and 70-122

70-449 Social, Economic and Information Networks

Spring: 9 units

Interaction is a fundamental part of social science: firms market products to consumers, people share opinions and information with their friends, workers collaborate on projects, agents form alliances and coalitions. In this course, we will use the emerging field of social networks to put structure on this diverse mass of connections. Using a mixture of theoretical, empirical, and computational methods, we will learn about the structure and function of social networks. We will look at how an individual's position in a social network reflects her role in the community. We will learn to identify tastemakers and trendsetters by looking at how information moves through our increasingly connected society. We will consider how our own position in the social network affects our behavior, opinions, and outcomes. And we will explore where social networks come from, and what affects their structure. The material in this course will be interdisciplinary, drawn from the fields of math, computer science, physics, sociology, political science, and economics. By the end of the course, you will have the tools and knowledge needed to analyze social networks on your own. The course is capped with a project where you will use your skills to answer your own questions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: (73-230 Min. grade C or 36-201 or 36-200) and (36-207 or 70-207 or 36-201)

70-452 Introduction to Product Management

All Semesters: 9 units

This course introduces the role and responsibilities of the Product Manager in a technology-intensive product or services company. The over-arching goal of the course is to give you the knowledge and tools you need to make good product decisions so that your team can ship the right product, to the right customers, through the right channels, at the right price. To that end, you will learn to apply tools and techniques for building and managing a product roadmap, prioritizing development requests, evaluating tradeoffs, and modeling the financial implications of different business models, operating models, pricing, and packaging options. Along the way, we will look at many of the core activities and tasks that an effective Product Manager needs to master, including: Understanding value propositions and customer priorities, Identifying and selecting customer and market segments, Packaging and bundling capabilities and benefits into a cohesive set of offerings, Selecting pricing models and setting specific prices, Estimating the likely benefits and costs of proposed product enhancements, Modeling and evaluating the financial implications of product choices, Managing the full product life cycle, from conception to sunset. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-453 Business Technology for Consulting

Intermittent: 9 units

In this course, you will learn to how to effectively lead and undertake information system analysis and design projects. In doing so you will develop your 'intellectual toolbox' for business technologies consulting by learning to apply specific tools and techniques such as BPMN and Agile development methodologies. You will practice applying these techniques on a variety of case studies, examples, and a substantial semester-long project. Beyond the concrete analysis and design techniques, you will develop a set of work practices and habits of thought that should serve you well in your consulting career. This will be a very hands-on course in which you will largely learn by doing. Most class sessions will include a combination of some presentation by the instructor, some discussion (possibly of a case study), and exercises to practice working with the day's tools and concepts. Homework assignments, in-class presentations, and a semester-long term project are essential parts of the course.

Prerequisites: 70-451 or 70-110

70-455 Data Management Fundamentals

Intermittent: 9 units

Data drives modern business. Transactional data systems keep the world's economy operating smoothly by tracking and processing the movement of bits, money, atoms, and attention across the planet. Analytic systems help managers understand and optimize their businesses. Robotic systems (both physical machines and software bots) are automating a tremendous amount of the work that has historically been done by people. In this course you will learn to use a set of data management tools to capture, manage, analyze, and understand data so to help your organization do business better, faster, and cheaper. This course was previously titled Modern Data Management. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 15-104 or 15-110 or 70-110 or 15-112

70-458 Advanced Data Management

Intermittent: 9 units

There's a lot of data out in the world. A LOT. It's not only being generated, captured, stored, and analyzed at a rate unlike anything seen in human history, but the rate at which all of this is happening is accelerating. Rapidly. For better and for worse, a lot of this data does not fit nicely into the clean, precise, and carefully structured tabular formats perfected by computer scientists and IT professionals in the latter part of the 20th century. Rather, this data (you've probably heard it called "Big Data", "Unstructured Data", "Loosely-Structured Data", "4k Video", etc.) comes in all sorts of shapes and sizes, and in volumes that are so large they require new ways of thinking about capturing, managing, and working with it. In this course, you will learn to work with big, loosely-structured data sets to better understand the world and make better decisions as you operate within it. We will explore a wide variety of different approaches to representing data (graphs, data documents, and key-value and key-pair, geo-polygons, Big Tables, massive text indices, etc.) and the tools that use those data stores to uncover insights and help you make good business decisions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisite: 70-455

70-460 Mathematical Models for Consulting

Intermittent: 9 units

This course will cover a wide variety of mathematical models and techniques that are used by consultants and lie at the heart of modern decision-support systems. We will discuss the benefits and limitations of different models and follow a practical spreadsheet-based approach to provide hands-on experience with Excel Solver. The course will build on the knowledge you have gained from the prerequisite courses; we will develop your model-building skills, explore some technique-oriented skills such as linear, integer, and nonlinear programming, and experiment with heuristic solution methods. While going through different models and techniques, we will also see real-world examples of how these models are actually used in practical business environments. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 21-257 or 21-292 or 70-257

70-462 Uncertainty and Risk Modeling

Intermittent: 9 units

This course takes the perspective of the consultant whose job is to analyze existing or potential business processes and provide recommendations for managerial decision-making. Recognizing that most businesses are subject to high levels of variability, risk and uncertainty, it will adopt a stochastic approach to characterize the behavior of business systems and processes, and explore the effects of alternative decisions in this context. Two modeling methodologies will be covered: (i) stochastic modeling, and (ii) stochastic simulation. Examples are drawn from different managerial domains, such as supply chain management, risk management, marketing, and project management. The lectures, homework assignments, exam and term project will focus on modeling, computational, and analytical skills. Computational implementations will be done in Excel using the @Risk add-in (during the first half of the course to build simple simulation models) and the Arena software (during the second half of the course to build more complex models based on discrete-event simulation). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-207 or 36-200 or 36-201 or 36-225 or 36-220 or 36-207

70-465 Technology Strategy

Intermittent: 9 units

This course is about business strategy for technology-intensive industries. Examples of such industries are computer hardware and software, media and entertainment, telecommunications and e-commerce. We will explore the unique economic circumstances facing firms in these industries and identify strategies that enable firms to succeed given these circumstances. You will learn to analyze pricing strategies including versioning and bundling; product standardization decisions; managing product complements; exploiting network effects; managing platform competition. This course will help you understand the unique economic characteristics seen in today's technology-intensive markets and how they impact the strategic interactions among firms and consumers. We will study, for example: Why firms in the IT industry give away their best products for free. Why makers of video gaming consoles subsidize end users (but tax game developers) while computer operating system makers subsidize software developers (but overcharge end users). Why Sony won the Blu-Ray format war against HD-DVD which was sponsored by a whole array of companies. In order to understand how firms strategically interact with consumers in technology-intensive industries this course will use a combination of simple but rigorous analytical models, emerging theories, and formal case studies.

Prerequisites: 21-120 and (21-259 or 21-256) and 73-100 and 73-230

70-467 Machine Learning for Business Analytics

Intermittent: 9 units

This course introduces students to the machine learning tools and software that drive modern predictive analytics in business settings. Students will gain an understanding of a variety of popular machine learning algorithms including linear and logistic regression, random forests, and neural networks. Each algorithm will be introduced with real-world business applications, and students will learn to implement these algorithms on data. The course is taught in the programming language R (prior programming experience is not required). This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: (21-254 or 21-256 or 21-259) and (70-207 or 36-225 or 36-220 or 36-200)

70-469 End to End Business Analytics

Intermittent: 9 units

Deriving value from business data is an integrative process. It requires putting together the virtuous pipeline of using the data to derive descriptive and diagnostic inferences, building explainable predictive models and incorporating them in prescriptive decision making. This course charts this process end-to-end by describing and integrating common tools for modeling uncertainty, machine learning, and optimization in the context of common applications from finance, marketing and operations. The coursework is based on data-driven cases that will have students analyzing data from real business applications to derive their own insights, predictions and decisions and communicating them effectively. The course will prepare students for careers in consulting and any form of business data analysis in any functional area. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: (36-200 or 36-220 or 36-225 or 70-207) and (21-257 or 70-257 or 21-292)

70-471 Supply Chain Management

Intermittent: 9 units

This course will discuss basic issues in supply chain management to answer how a company should design its supply chain and how a company should administer its operations policy to satisfy the company's business strategy. We will also examine how firms interact with other entities within the supply chain, and how one can turn the system/network of entities across the supply chain to its own advantage by capturing economic surplus effectively. Special attention will be paid to analyzing the strengths and weaknesses of supply chains from a strategic, qualitative level. At the same time, we will also learn how to make effective trade-offs in operational decisions from a tactical, quantitative level. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student.

Prerequisite: 70-371

70-476 Service Operations Management

Intermittent: 9 units

The service sector accounts for approximately 70% of the GDP and 85% of the jobs in the United States. Given the ever-increasing role of services in the economy, it is crucial for a manager to understand both how services differ from manufacturing operations and how traditional operations management techniques can be applied to services. This course provides a general managers perspective on strategic analysis as well as operational decision making. The course will examine settings in traditional service businesses such as financial services (banking), retail environments, and transportation (airlines), and health-care sector. The Additional topics include evaluation of management of service quality, variability and customer waits, and revenue management. The course is intended for students interested in general management, consulting, financial services, or operations.

Prerequisites: (36-208 or 70-208 or 36-202) and 70-371

70-477 Real Options: Creating Value Beyond NPV

Intermittent: 9 units

Real options analysis is an approach to the management of operational assets that exploits managerial flexibility in decision-making and combines it with market-driven valuation of cash flows. It is thus particularly useful when managing projects that involve dynamic and state-contingent choices among alternatives (options), especially of a strategic nature. The valuation of financial options is the conceptual basis of real options management (but this course does not assume prior knowledge of this topic). Real options analysis extends this fundamental market-driven valuation approach to a much broader spectrum of business applications that feature dynamic decision-making. It thus contrasts the standard net present value rule used by static discounted cash flow analysis. The resulting managerial decisions and asset valuations can be very different when real options analysis is used rather than static discounted cash flow analysis. The course learning objectives are to (i) develop the students ability to take an unstructured problem and implement real options analysis in a structured manner; (ii) integrate market-driven valuation and dynamic decision-making techniques into a practical, yet rigorous, business analytics toolkit; and (iii) provide examples of successful practice and applications in a variety of industries. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-480 International Marketing

Intermittent: 9 units

This course is designed to provide students with a basic understanding of global marketing opportunities, key issues, and strategies. It introduces the main characteristics of international markets and addresses the impact of global environmental factors (economic, social, legal, and cultural) on marketing decisions such as market entry, product development, pricing, promotion, and distribution. The objective of the course is to help students acquire knowledge of major international marketing concepts and develop cross-cultural sensitivities and skills that would enable them to identify, analyze, and solve international marketing problems. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-481 Marketing Research

Intermittent: 9 units

The purpose of this course is to teach multiple research techniques used in marketing. This course is an applied marketing course that gives insight into how various techniques are used in marketing research firms. There are three projects and a final. The first project is designed to teach students about research survey methods. The second is an experiment in which the whole class is involved. The third, an individual project, is designed to teach quantitative research techniques. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: (36-202 or 70-208) and 70-381

70-482 Pricing Strategy

Intermittent: 9 units

Pricing is a critical marketing decision which enables a firm to translate customer value into profit. This course provides a first survey of pricing concepts. Instead of discussing pricing in isolation, we focus on the interplay between pricing and other aspects of marketing, such as positioning, branding and advertising. To this end, we provide a formal treatment of pricing concepts in the framework of game theory. Finally, we also discuss non-pricing tools that firms can use in order to capture customer value. Specifically, we cover cases wherein firms generate a profit while keeping their services free, a phenomena that is widely observed among Internet firms. This course has no formal prerequisite, but a willingness to study formal (i.e., mathematical) models is assumed. Any previous exposure to microeconomics analysis and game theory will be helpful. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-483 Advertising and Marketing Communications

Intermittent: 9 units

It is critical that marketers understand the limitations of marcom tactics as well as how to best leverage and integrate marcom tactics for the strongest, most consistent and authentic brand voice in the targeted marketplace. The entire IMC process is driven by the customer, and in the case of our discussions in this class, the consumer. The course is designed to help students understand the integrated marketing communications model, the strategy and tools of the marketing mix and what makes an iconic brand. The course is designed in five sections: Part One focuses on understanding brands - iconic brands, terminology and types of branding. Part Two focuses on the understanding of consumer behavior - one of the, if not the most critical part of understanding marketing. Brands are built and defined in the minds of consumers. Part Three focuses on IMC and the framework used by brand management to develop strategy, and understand audience segmentation and brand positioning to drive IMC. Part Four focuses on understanding the IMC tactics available to marketers including advertising, social media and digital marketing, events and public relations. Part five concludes with the deeper study of an iconic brand. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-381

70-484 Data Science for Finance

Intermittent: 9 units

This course first reviews the fundamentals of Financial Data Science with Python. The course then introduces several financial applications that rely heavily on data analytics, including 1) Algorithmic Trading, 2) Quantitative portfolio management, and 3) "Smart" beta and performance analysis. The class uses tools from statistics, machine learning and natural language processing. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-391 and (36-202 or 70-208 or 36-208)

70-485 Product and Brand Management

Intermittent: 9 units

Product managers are essentially the "CEO" of the product line. Brand and product management provides strategic vision and leadership for the product and service, both 1) understanding the market opportunity and what must be done for successfully delivering on the brand promise and 2) leading across the organization, often without authority, to achieve that success. Product/service success in a dynamic market is subject to many factors, including marketplace needs, reactions and activities of competition, the strategy and change within one's own firm, operating and financial constraints, demand forecast uncertainty, and more. By taking this course, you will learn the principles of product and brand management and understand what it is like and what it takes to be a successful marketing leader. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisite: 70-381

70-488 Marketing Digital Media

Spring: 6 units

(Formerly titled "Interactive Marketing") In this course we analyze how marketing practice changes when products are distributed and consumed in digital formats. This course focuses on several areas where digitization is likely to have the most profound affect on the field of marketing. These areas include promotion, competitive strategy, channel conflict, pricing, and identifying and differentiating customers. We will use both lectures, cases, and analysis of real-world datasets to analyze these issues. Prerequisite: 70-381

70-490 Big Data in Finance and Machine Learning

Spring: 12 units

This course deals with the financial decisions of corporations. The focus is on learning through "hands-on" experience of the corporate world, supplemented by a discussion of theoretical concepts and analysis of data. This "hands-on" experience is in computerized lab games that simulate the corporate world, in which students participate as CEO's, investors, and directors. Topics to be covered include the following: dividend policy; financial reporting; CEO compensation; and valuation. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75. Prerequisites: 70-391 and 70-122

70-492 Investment Analysis

Intermittent: 9 units

Investment analysis provides you the concepts and tools used to analyze publicly traded securities, and you will learn how to use these tools to real world situations. The course is organized as a tour of the different kinds of securities used in the financial markets. You will analyze how security prices are determined, the relations between the prices of different securities, their risks and returns, and how to choose a portfolio or strategy from different asset classes. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 70-391 or 21-370

70-493 Valuation and Financial Modeling

Intermittent: 9 units

This course focuses on valuing companies. Students will learn theoretical valuation frameworks and then apply them practically. The class will cover a range of valuation approaches including discounted cash flow analyses, price multiples, real options and the venture capital method. The class will be very hands-on - we will be building valuation models in excel in-class and in case assignments using real-world data such as company financial statements and stock prices. This is particularly useful for students considering careers in investment banking and private equity. We will focus not just on learning valuation methods but also understanding the assumptions that underlie them. We will ask when such assumptions are trivial and when they can lead to large errors. We will value a variety of companies including Ferrari, WhatsApp and Snap Inc. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisite: 70-391

70-495 Corporate Finance

Spring: 9 units

Students develop an advanced financial perspective on how firms make investment, financing, and management decisions. The course starts with simple net present value rules and builds the theoretical framework to address more sophisticated issues and problems including risk management, mergers, acquisitions, executive compensation, corporate governance, and dividend payout policies. Theory is supplemented with numerous case study examples. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student.

Prerequisites: 70-391 or 21-370

70-497 Derivative Securities

Intermittent: 9 units

This course has two goals. The first goal is to help you to master the tools to price and hedge and understand the risk exposures of any contingent claim on any underlying variable. The second goal in this course is to practice using these pricing and hedging tools in derivative structuring and sales. The focus here is on designing and pricing derivative securities to trade on specialized market views and to hedge customized risk exposures. The course also highlights practical issues about model calibration, model risk, and dynamic and static hedging. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 21-370 or 70-391

70-498 Business Language Analytics: Mining Financial Texts and Graphs

Spring: 9 units

This course provides students with hands-on experience in applying data mining tools to analyze business language, both text and numbers, used in formal documents written following specific accounting language rules. Accounting numbers: Accounting numbers obey a basic double-entry bookkeeping structure leading to a graph representation. One half of the course covers recent graph mining techniques to examine accounting data for solving problems such as pattern recognition and anomaly detection. Accounting texts: While texts in accounting documents are written in natural language they must obey regulatory disclosure requirements in both substance and form. The second half of the course shows students how Data in text form from accounting disclosures such as annual reports or earnings conference calls can be examined systematically using textual analysis techniques to gain further insight and knowledge about reporting firms and industries beyond those inferred from non-textual data. Examples include measures of readability to assess communication effectiveness, the analysis of tone as a measure of uncertainty or as a predictor of performance, and topic classification to quantify similarity or incremental information. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisite: 70-122

70-499 Internship

Fall and Spring: 3 units

Students doing a business-related internship for academic credit may enroll in this course for three units with a pass/no pass grade. Students must submit an internship agreement form to the instructor for approval prior to the start of the internship. A summary writing assignment must be submitted after the internship in order to receive credit. Enrollment with special permission. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

70-500 Honors Thesis I

Fall and Spring

Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA department. Enrollment by permission of the BA Program.

70-501 Honor Thesis II

Fall and Spring

Business students with outstanding academic records may undertake an Honors Thesis. The topic is of the student's choice but must have some original aspect in the question being explored, the data set, or in the methods that are used. It must also be of sufficient academic rigor to meet the approval of a faculty advisor with expertise in the project's area. Students enroll each semester in a 9-unit independent study course with their faculty advisor for the project (70-500 in the fall and 70-501 in the spring). Students and their faculty advisor develop a course description for the project and submit it for approval as two 9-unit courses to the BA Director. Enrollment by permission of the BA Program.

70-502 Independent Study in Management

Fall and Spring

Students with a special interest in Management/Production not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA program. This course uses course material that requires students to pay an additional course fee. The course material is secured by the Tepper School because it is otherwise unavailable and directly provided to each student.

70-503 Independent Study in Marketing

All Semesters

Students with a special interest in Marketing not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-504 Independent Study in Organizational Behavior

All Semesters

Students with a special interest in Organizational Behavior not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-505 Independent Study in Finance

All Semesters

Students with a special interest in Finance not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-506 Independent Study in Business Analytics and Technology

All Semesters

Students with a special interest in Business Analytics and Technologies not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-507 Independent Study in Business Communications

All Semesters

Students with a special interest in Business Communications not covered by a formal Business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-508 Independent Study in International Management

All Semesters

Missing Course Description - please contact the teaching department.

70-509 Independent Study in Entrepreneurship

All Semesters

Students with a special interest in entrepreneurship and innovation not covered by a formal business course may develop an Independent Study Course in that area. Readings and work to be completed are by agreement between the student and an individual faculty member. Enrollment by permission of the BA Program.

70-515 Independent Study in Operations Management or Operations Research

Intermittent

For students completing an independent study in operations management or operations research; consult the business administration program for independent study information.

Undergraduate Economics Program

Burton Hollifield, Associate Dean, Undergraduate Programs; PNC Professor of Finance; Professor of Financial Economics

Jennifer Wegner, Assistant Dean, Undergraduate Programs

Location: Tepper Quad, Suite 2400

Email: econprog@andrew.cmu.edu

Advising Appointment Online Scheduler: <https://meetme.so/TepperAdvising>
www.cmu.edu/tepper/programs/undergraduate-economics (<http://www.cmu.edu/tepper/programs/undergraduate-economics/>)

At its most fundamental level, economics is the study of how scarce resources are allocated. What will be produced and consumed, how much, and by whom? These questions are central to the well-being of people throughout the world. Economists identify, model, and analyze problems with the objective of developing practical and efficient solutions to challenges confronting society. Economists are also active participants in the processes and institutions through which economic policies are implemented. In the public arena sphere, economists contribute to the design of programs and incentive systems to foster efficient implementation of policies. In the private sector, economists use modeling and data-analytic skills, both in identifying ways to enhance productive efficiency within the firm and in developing strategies to enhance effectiveness of the firm as it competes in the global marketplace.

Upon major declaration, students pursuing the Bachelor of Arts in Economics or Bachelor of Science in Economics are affiliated with the Tepper School of Business. This means that students complete the Tepper general education requirements and are subject to all Tepper School policies and procedures. Students interested in the Bachelor of Science in Economics+Mathematics first declare the Bachelor of Science in Economics degree and are then able to apply for Economics+Mathematics major. The academic college affiliation for students pursuing majors in Economics +Politics and Economics+Statistics is the Dietrich College of Humanities and Social Sciences.

EDUCATIONAL OBJECTIVES

The Economics majors are designed to develop strong analytical skills and a solid foundation in the discipline of economics. More specifically, measurable objectives for our economics curriculum are the following:

- Students should be able to identify, explain, and use economic concepts, theories, models, and data-analytic techniques.
- Students should acquire and use knowledge of economics, mathematics, statistics, and computing flexibly in a variety of contexts, providing the foundation for success in graduate studies and careers in the public and private sectors.
- Students should be able to apply their economic tools to formulate positions on a wide range of social and economic problems and engage effectively in policy debates.
- Students should use the investigative skills necessary for conducting original economic research and participating effectively in project teams.
- Students should be able to deliver effective presentations in which they combine visual communication design with oral arguments and/or the written word.

Degree Options

In order to accommodate students' wide variety of goals, three primary degree majors are available in the Tepper School of Business:

- Bachelor of Arts in Economics
- Bachelor of Science in Economics
- Bachelor of Science in Economics and Mathematical Sciences (jointly administered with the Department of Mathematics)

The Dietrich College of Humanities and Social Sciences administers two interdisciplinary Economics majors:

- Bachelor of Science in Economics and Politics
- Bachelor of Science in Economics and Statistics

For students who major in other academic fields, additional major programs in Economics, Economics and Politics, and Economics and Statistics, and a minor degree program in Economics are available.

B.A. in Economics

To receive the B.A. degree in Economics, students must complete at least 360 units, consisting of the requirements for Mathematics, Quantitative Analysis, Economic Core, Economic Electives, Senior Requirement, University Core, and a Minor.

Mathematics Prerequisites

| Courses | Units |
|--|-------|
| 21-120 Differential and Integral Calculus | 10-20 |
| or 21-111 Calculus I & 21-112 and Calculus II | |
| 21-256 Multivariate Analysis | 9-10 |
| or 21-259 Calculus in Three Dimensions | |

Economic Theory Requirements

| Courses | Units |
|--|-------|
| 73-102 Principles of Microeconomics | 9 |
| or 73-104 Principles of Microeconomics Accelerated | |
| 73-103 Principles of Macroeconomics | 9 |
| 73-230 Intermediate Microeconomics | 9 |
| 73-240 Intermediate Macroeconomics | 9 |
| 70-340 Business Communications | 9 |
| 70-345 Business Presentations | 9 |

Quantitative Analysis Requirements

| Courses | Units |
|---|-------|
| 70-207 Probability and Statistics for Business Applications | 9 |
| or 36-200 Reasoning with Data | |
| 73-265 Economics and Data Science | 9 |
| 73-274 Econometrics I | 9 |

Economics Electives (36 Units)

Students must take four economics elective courses. Economics elective courses are those numbered 73-300 or higher.

Special Electives (18 Units)

Students must take two special elective courses. Students should consult the degree audit system for courses that satisfy the special electives requirement.

Course List

| Sample List of Special Elective Courses | Units |
|---|-------|
| 19-402 Telecommunications Technology and Policy for the Internet Age | 12 |
| 19-403 Policies of Wireless Systems | 12 |
| 19-411 Science and Innovation Leadership for the 21st Century: Firms, Nations, and Tech | 9 |
| 19-421 Emerging Energy Policies | 9 |
| 19-425 Sustainable Energy for the Developing World | 9 |
| 66-221 Topics of Law: Introduction to Intellectual Property Law | 9 |
| 79-245 Capitalism and Individualism in American Culture | 9 |
| 79-262 Modern China: From the Birth of Mao ... to Now | 9 |
| 79-266 Russian History and Revolutionary Socialism | 9 |
| 79-280 Coffee and Capitalism | 9 |

| | | |
|--------|---|---|
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-383 | The History of Capitalism | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-305 | Game Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 84-310 | International Political Economy | 9 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 88-411 | Rise of the Asian Economies | 9 |

Senior Work

| | | |
|--------------------|--|-------|
| | | Units |
| 73-497 | Senior Project | 9 |
| or 73-500 & 73-501 | Tepper College Honors Thesis I and Tepper College Honors Thesis II | |

Note: Students in the BA in Economics who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

MINOR

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor is waived.

UNIVERSITY CORE

Students are required to complete the Tepper University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (<http://coursecatalog.web.cmu.edu/search/?P=99-101>) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

B.S. in Economics

To receive the B.S. degree in Economics, students must complete at least 360 units, consisting of the requirements for Mathematics, Quantitative Analysis, Economic Core, Economic Electives, Senior Requirement, University Core, and a Minor.

Mathematics Requirement

| | | |
|--------------------|-------------------------------------|-------|
| | | Units |
| 21-120 | Differential and Integral Calculus | 10-20 |
| or 21-111 & 21-112 | Calculus I and Calculus II | |
| 21-256 | Multivariate Analysis | 9 |
| or 21-259 | Calculus in Three Dimensions | |
| 21-240 | Matrix Algebra with Applications | 10 |
| or 21-241 | Matrices and Linear Transformations | |

Quantitative Analysis Requirements

| | | |
|-----------|---|-------|
| | | Units |
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |
| 73-374 | Econometrics II | 9 |
| or 73-423 | Forecasting for Economics and Business | |
| or 70-467 | Machine Learning for Business Analytics | |

Economic Core Requirements

| | | |
|-----------|--|-------|
| | | Units |
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 70-340 | Business Communications | 9 |
| 70-345 | Business Presentations | 9 |

Economics Electives (54 Units)

Students must take six economics elective courses. Economics elective courses are those numbered 73-300 or higher.

Senior Requirement

| | | |
|--------------------|--|-------|
| | | Units |
| 73-497 | Senior Project | 9 |
| or 73-500 & 73-501 | Tepper College Honors Thesis I and Tepper College Honors Thesis II | |

Note: Students in the BS in Economics who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

MINOR

In order to obtain the degree, students must complete a minor from another academic department. For students electing to complete an additional major or dual degree, the minor requirement is waived.

UNIVERSITY CORE

Students are required to complete Tepper University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (<http://coursecatalog.web.cmu.edu/search/?P=99-101>) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

B.S. in Economics and Mathematical Sciences

The B.S. in Economics and Mathematical Sciences is an interdisciplinary major that provides students with courses that complement and develop depth of understanding of economic theory, applied economics, and applied mathematics. The major equips students with the mathematical tools that are essential for success in Ph.D. programs in economics, mathematics, and key functional areas of business including finance, accounting, marketing, and information systems. Students must be enrolled in the B.S. in Economics major to apply for the Economics and Mathematics major. Acceptance into the major is based on meeting the following requirements:

- Cumulative QPA of at least 3.5
- Earned a "B" or better in 21-127 Concepts of Mathematics or 21-128 Mathematical Concepts and Proofs
- Earned a "B" or better in 21-241 Matrices and Linear Transformations
- Completed Principles of Microeconomics waiver, 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated
- Earned a "B" or better in 73-103 Principles of Macroeconomics

- Earned a "B" or better in either 73-230 Intermediate Microeconomics or 73-240 Intermediate Macroeconomics
- Personal statement

B.S. in Economics and Mathematical Sciences

Economic Theory Requirements

| | |
|--|-------|
| | Units |
| 73-102 Principles of Microeconomics * | 9 |
| or 73-104 Principles of Microeconomics Accelerated | |
| 73-103 Principles of Macroeconomics | 9 |
| 73-230 Intermediate Microeconomics | 9 |
| 73-240 Intermediate Macroeconomics | 9 |

Quantitative Analysis Requirements

| | |
|---|-------|
| | Units |
| 70-207 Probability and Statistics for Business Applications | 9 |
| or 36-200 Reasoning with Data | |
| 36-225 Introduction to Probability Theory | 9 |
| or 36-235 Probability and Statistical Inference I | |
| or 36-217 Probability Theory and Random Processes | |
| or 21-325 Probability | |
| 73-265 Economics and Data Science | 9 |
| 73-274 Econometrics I | 9 |
| 73-374 Econometrics II | 9 |

Mathematical Sciences Requirements

| | |
|---|-------|
| | Units |
| 21-120 Differential and Integral Calculus | 10-20 |
| or 21-111 Calculus I | |
| & 21-112 and Calculus II | |
| 21-122 Integration and Approximation | 10 |
| 21-127 Concepts of Mathematics | 12 |
| 21-228 Discrete Mathematics | 9-12 |
| or 15-251 Great Ideas in Theoretical Computer Science | |
| 21-241 Matrices and Linear Transformations | 11 |
| 21-259 Calculus in Three Dimensions | 9-11 |
| or 21-256 Multivariate Analysis | |
| or 21-268 Multidimensional Calculus | |
| or 21-269 Vector Analysis | |
| 21-260 Differential Equations | 9 |
| 21-355 Principles of Real Analysis I | 9 |
| 21-356 Principles of Real Analysis II | 9 |

Programming Requirement (10 Units)

| | |
|--------------------------------|-------|
| | Units |
| 15-110 Principles of Computing | 10 |

Writing Requirement

| | |
|--------------------------------|-------|
| | Units |
| 70-340 Business Communications | 9 |

Economic Electives (27 Units)

Students must take three economics elective courses. Economics elective courses are those courses numbered 73-300 through 73-495, (excluding 73-374 Econometrics II). Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Economics Electives:

| | |
|--|---|
| 73-315 Market Design | 9 |
| 73-338 Financial Crises and Risk | 9 |
| 73-347 Game Theory Applications for Economics and Business | 9 |
| 73-365 Firms, Market Structures, and Strategy | 9 |
| 73-421 Emerging Markets | 9 |

Mathematical Science Depth Electives (27 Units)

Students must take three advanced mathematics depth courses. Students are encouraged to work with their advisors to structure a set of courses which meet these requirements based on their particular interests, subject to course availability.

Recommended Mathematical Science Depth Electives:

| | |
|---|----|
| 21-270 Introduction to Mathematical Finance | 9 |
| 21-292 Operations Research I | 9 |
| 21-301 Combinatorics | 9 |
| 21-341 Linear Algebra | 9 |
| 21-369 Numerical Methods | 12 |
| 21-370 Discrete Time Finance | 9 |
| 21-371 Functions of a Complex Variable | 9 |
| 21-393 Operations Research II | 9 |
| 21-420 Continuous-Time Finance | 9 |
| 21-484 Graph Theory | 9 |

Note: Only one of the following courses may count towards the required Mathematical Sciences Depth Electives: 21-365 Projects in Applied Mathematics or 21-366 Topics in Applied Mathematics.

Senior Work (9 units; 18 units for students completing an honors thesis in economics)

| | |
|--|---|
| 73-497 Senior Project | 9 |
| or 73-500 Tepper College Honors Thesis I | |
| & 73-501 and Tepper College Honors Thesis II | |

Note: Students in the BS in Economics and Math who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

DOUBLE-COUNTING RESTRICTION

The 3 economics electives and 3 math electives cannot double count with another major or minor.

UNIVERSITY CORE

Students are required to complete University Core, general education coursework in the liberal arts and sciences.

COMPUTING @ CARNEGIE MELLON

All undergraduate students are required to take 99-101 (<http://coursecatalog.web.cmu.edu/search/?P=99-101>) Computing @ Carnegie Mellon to graduate (usually taken prior to the start of the first year or during the first year). The course focuses on Carnegie Mellon tools and technologies.

Additional Major in Economics

Students are eligible to apply for the Additional Major in Economics after completion of the Minor in Economics.

Mathematics Requirement

| | |
|--|----|
| 21-120 Differential and Integral Calculus | 10 |
| or 21-111 Calculus I | |
| & 21-112 and Calculus II | |
| 21-256 Multivariate Analysis | 9 |
| or 21-259 Calculus in Three Dimensions | |
| or 21-254 Linear Algebra and Vector Calculus for Engineers | |
| 21-240 Matrix Algebra with Applications | 10 |
| or 21-241 Matrices and Linear Transformations | |

Quantitative analysis requirement

| | |
|---|---|
| 73-265 Economics and Data Science | 9 |
| 73-274 Econometrics I | 9 |
| 73-374 Econometrics II | 9 |
| or 73-423 Forecasting for Economics and Business | |
| or 70-467 Machine Learning for Business Analytics | |

Economic Core Requirement

| | | |
|-----------|--|---|
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |
| 70-340 | Business Communications | 9 |
| 70-345 | Business Presentations | 9 |

If a student is pursuing the additional major and receives a prerequisite waiver for 73102, 9 additional units of elective course work (73xxx) is required.

Economics Electives Requirement (54 units)**Senior Requirement**

| | | |
|-----------|-------------------------------------|---|
| 73-497 | Senior Project * | 9 |
| or 73-500 | Tepper College Honors Thesis I | |
| & 73-501 | and Tepper College Honors Thesis II | |

Note: Students who complete an Honors Thesis in economics may use 73-497 (Senior Project) as an economics elective.

double count restriction

Students pursuing the additional major may double-count two economics electives with any other major or minor requirements. There are no double counting restrictions between the additional major and a student's home college general education requirements.

Dual Degree

Students intending to pursue a Dual Degree in Economics are required to apply for the dual degree and encouraged to consult with the Assistant Dean about their interests and application process. In addition to the student's primary degree requirements, a student accepted for Dual Degree in Economics is required to complete an overall number of units that exceeds the minimum unit requirement for the degree with the smaller unit requirement, by at least 90 units. Further, they must meet all requirements for the economics major including the Tepper's University Core requirement. The student's primary major will substitute for the minor requirement. The student's primary major must be completed prior to or at the same time as the dual degree in Economics to satisfy the minor requirement.

Minor in Economics

Students are eligible to apply for a minor upon completion of two required courses for the minor wherein they earn a 2.0 QPA or higher in said coursework.

While there are no double counting restrictions between the minor and the student's home college general education requirements, 73-265 Economics and Data Science and the 3 economics electives must be unique for the minor and cannot double count with any other major or minor.

Mathematics Requirements

| | | Units |
|-----------|--|-------|
| 21-120 | Differential and Integral Calculus | 10-20 |
| or 21-111 | Calculus I | |
| & 21-112 | and Calculus II | |
| 21-256 | Multivariate Analysis | 9 |
| or 21-254 | Linear Algebra and Vector Calculus for Engineers | |
| or 21-259 | Calculus in Three Dimensions | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |

Economic Theory Requirements (27 Units)

| | | Units |
|-----------|--|-------|
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |

or 73-240 Intermediate Macroeconomics

If a student is pursuing an economics minor and receives a prerequisite waiver for 73102, 9 additional units of elective course work (73xxx) is required to ensure 54+ units are met in the minor curriculum.

Quantitative Analysis Requirements (18 Units)

Students who have taken coursework in intermediate-level regression analysis and data visualization may petition to substitute 73-274 Econometrics I or 73-423 Forecasting for Economics and Business for 73-265 Economics and Data Science.

| | | Units |
|-----------|--|-------|
| 70-207 | Probability and Statistics for Business Applications | 9 |
| or 36-200 | Reasoning with Data | |
| or 15-259 | Probability and Computing | |
| or 21-325 | Probability | |
| or 36-218 | Probability Theory for Computer Scientists | |
| or 36-219 | Probability Theory and Random Processes | |
| or 36-220 | Engineering Statistics and Quality Control | |
| or 36-225 | Introduction to Probability Theory | |
| or 36-247 | Statistics for Lab Sciences | |
| 73-265 | Economics and Data Science | 9 |

Economics Electives (27 Units)

Students must take three economics elective courses. Economics elective courses are those numbered 73-3xx through 73-49x. Students are encouraged to work with their economics advisor to structure a set of courses to meet these requirements based on their particular interests, subject to course availability.

Economics Policies and Procedures**Course double counts**

Students cannot double count courses within the Economics curriculum. When choosing to double-count courses between Tepper and other academic departments, the double-count policies are determined by the other academic department for a minor, additional major, and/or dual degree. There are no double-counting restrictions between the minor and the student's home college general education requirements.

Non-Tepper students earning a minor, additional major, or dual degree in Economics must adhere to the policies listed in the catalog for double counting courses. Students pursuing multiple Tepper minors cannot double count beyond one course across the minors. There are no double-counting restrictions between the minor or additional major and the student's home college general education requirements.

External Transfer Credit

Courses taken at higher education institutions outside of Carnegie Mellon can be considered for transfer credit through the Tepper School course equivalency process.

BA in Economics: May transfer a maximum of 18 units of economics elective course credit;
 BS in Economics: May transfer a maximum of 18 units of economics elective course credit;
 BS in Economics and Math: May transfer a maximum of 9 units of economics elective course credit;
 Additional Major in Economics: May transfer a maximum of 18 units of economics;
 Minor in Economics: May transfer a maximum of 18 units of economics elective course credit.

FIRST YEAR ACADEMIC ADVISING

First-year students interested in economics begin as Dietrich College students and are assigned a Dietrich College Academic Advisory Center (<http://www.cmu.edu/hss/advisory-center/>) (AAC) advisor. While the AAC advisors are the advisors of record until students formally declare their majors, students who are considering majoring in economics are encouraged to speak with the Tepper School Economics advisors so that they will have access to program resources, advising, and the community of faculty, staff, and students.

MINIMUM GRADE STANDARD

All economics courses (73-xxx and higher) counting towards an economics degree must be completed with a grade of "C" or higher. Students who fail to receive a grade of "C" or better in an economics course prerequisite will be dropped or not permitted to enroll in the associated economics course.

senior Experience

The senior experience curriculum requirement can be met through completion of 73-497 Senior Project or the honors thesis. The senior project course 73-497 can be an upper-level economics elective if students are completing an Honors Thesis and earning the BA in Economics, BS in Economics, BS in Economics and Math, or BS in Economics and Politics. 73-497 does not count as an upper-level economics elective for students pursuing the BS in Economics and Statistics.

Transferring into Economics

The Economics program accepts applications for transfer admission from any academic institution outside of Carnegie Mellon University on a limited basis. Students interested in transfer should contact Carnegie Mellon's Office of Admission.

The program also accepts applications for a major change from current Carnegie Mellon students who are in other academic programs to begin in either the fall or spring semester. To be considered, a student must have successfully completed a Carnegie Mellon math course required in the economics program (21-256 Multivariate Analysis 21-256 Multivariate Analysis 21-254 Linear Algebra and Vector Calculus for Engineers 21-254 Linear Algebra and Vector Calculus for Engineers or 21-259 Calculus in Three Dimensions 21-259 Calculus in Three Dimensions) and 73-102 Principles of Microeconomics or 73-104 Principles of Microeconomics Accelerated 73-104 Principles of Microeconomics Accelerated and 73-103 Principles of Macroeconomics. The application also requires a resume and personal statement. CMU students interested in changing to a Tepper major must complete the internal transfer application by the deadline which is always the last day of class in the semester preceding the desired semester for transfer. Successful transfer is limited by space.

Faculty

LAURENCE ALES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2008-

SERRA BORANBAY AKAN, Assistant Teaching Professor of Economics – Ph.D., Northwestern University; Carnegie Mellon, 2013-

JAMES A. BEST, Assistant Professor of Economics – Ph.D., University of Edinburgh; Carnegie Mellon, 2018-

DAVID CHILDERS, Assistant Professor of Economics – Ph.D., Yale University; Carnegie Mellon, 2016-

KAREN B. CLAY, Professor of Economics and Public Policy, H. J. Heinz III College – Ph.D., Stanford University; Carnegie Mellon, 1998-

ROBERT M. DAMMON, Richard C. Green Professor of Financial Economics – Ph.D., University of Wisconsin; Carnegie Mellon, 1984-

KENNETH B. DUNN, Professor of Financial Economics, Emeritus – Ph.D., Purdue University; Carnegie Mellon, 1979-

DENNIS N. EPPLE, Thomas Lord University Professor of Economics – Ph.D., Princeton University; Carnegie Mellon, 1974-

SELMAN EROL, Assistant Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2016-

CHRISTINA FONG, Senior Research Scientist in Social and Decision Sciences, Dietrich College of Humanities and Social Sciences – Ph.D., University of Massachusetts; Carnegie Mellon, 2001-

JOHN GASPER, Associate Teaching Professor of Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 2010-

MARTIN GAYNOR, E.J. Barone University Professor of Economics and Health Policy, H. J. Heinz III College – Ph.D., Northwestern University; Carnegie Mellon, 1995-

BURTON HOLLIFIELD, Associate Dean, Undergraduate Programs; PNC Professor of Finance; Professor of Financial Economics – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1999-

KARAM KANG, Associate Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 2012-

ALEXEY KUSHNIR, Associate Professor of Economics – Ph.D., Pennsylvania State University; Carnegie Mellon, 2014-

FINN KYDLAND, The Richard P. Simons Distinguished Professorship; University Professor of Economics, Emeritus; Nobel Laureate (2004) – Ph.D., Carnegie Mellon University; Carnegie Mellon, 1977-

REBECCA LESSEM, Associate Professor of Economics – Ph.D., University of Wisconsin-Madison; Carnegie Mellon, 2011-

BENNETT T. MCCALLUM, H. J. Heinz Professor of Economics, Emeritus – Ph.D., Rice University; Carnegie Mellon, 1981-

ROBERT A. MILLER, Richard M. Cyert and Morris DeGroot Professor of Economics and Statistics – Ph.D., University of Chicago; Carnegie Mellon, 1982-

NICHOLAS Z. MULLER, Professor of Economics, Engineering, and Public Policy – Ph.D., Yale University; Carnegie Mellon, 2017-

ANH NGUYEN, Assistant Professor of Economics – Ph.D., Columbia University; Carnegie Mellon, 2018-

JOHN R. O'BRIEN, Associate Professor of Accounting and Experimental Economics, Emeritus – Ph.D., University of Minnesota; Carnegie Mellon, 1984-

MARGARITA PORTNYKH, Distinguished Service Professor of Economics – Ph.D., Clemson University; Carnegie Mellon, 2018-

MARYAM SAEEDI, Assistant Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016-

ALI SHOURIDEH, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2016-

FALLAW B. SOWELL, Associate Professor of Economics – Ph.D., Duke University; Carnegie Mellon, 1988-

CHESTER S. SPATT, Pamela R. and Kenneth B. Dunn Professor of Finance – Ph.D., University of Pennsylvania; Carnegie Mellon, 1979-

STEPHEN E. SPEAR, Professor of Economics – Ph.D., University of Pennsylvania; Carnegie Mellon, 1982-

ARIEL ZETLIN-JONES, Associate Professor of Economics – Ph.D., University of Minnesota; Carnegie Mellon, 2012-

Undergraduate Economics Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

73-003 Transfer Credit

All Semesters

This number "holds" a place for an economics transfer credit courses so that these courses can be used in the academic audit system. Student receiving 73-003 credit have met the requirement of earning the equivalent of a "C" in their non-CMU economics course; however, have not earned the equivalent of a "B" which would provide credit for a CMU economics course equivalency.

73-060 Economics: BaseCamp

Fall: 3 units

This short course will launch you into the economics intellectual space and get you thinking like an economist. Through a series of presentations by some of CMU's great economics thinkers you will learn how economic reasoning harnessed to data can lead to better policy design and better business decision making. Presentations may cover the economics of bitcoin and crypto-currency, online market design, financial crises, the future of work, how to become involved in economics research, healthcare, the environment, and other topics. The presentations will be curated by one of CMU's research economists and there will be plenty of opportunities for discussion and debate. The course will also introduce you to the CMU approach to economics and map out the CMU economics major landscape.

73-065 Nudging Behavior in Business and Public Policy

Spring: 3 units

This course applies the insights of Behavioral Economics to inform business and policy decisions. A nudge encourages desired behavior by framing the decision or environment such that various cognitive processes and heuristics are engaged in favor of the desired outcome. The use of this branch of social science has been used successfully by the UK and US governments by the Behavioural Insights Team and Social and Behavioral Sciences Team, respectively. Nudges have also been used effectively by the United Nations, via UNICEF, to address and change a variety of behaviors such as gender violence and sanitation practices. In 2016 the Supreme Committee for Delivery and Legacy founded the Qatar Behavioral Insights Unit (QBIU) and it was incorporated as a foundation under the Qatar Financial Center in 2019. This foundation is known as B4Development (B4D) and would be of interest and importance to CMUQ students. One of the partners of B4D is the Qatar Foundation.

73-102 Principles of Microeconomics

Fall and Spring: 9 units

The course is an introduction to microeconomic principles and how to think like an economist. Market and policy outcomes are largely a function of individual decisions. These questions typically take the form: how much and what combination of things should I buy? When do we want businesses to go bust? Should the government fund student tuition? It's my hope that you'll also start to think about everyday questions from an economic lens: why were bicycles so hard to find this past summer? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of government in the marketplace. Toward the end of the semester, we'll change a few underlying assumptions and address a variety of questions related to strategic interaction. Some of the topics we will begin to introduce include credible threats, commitment problems, and the strategic use of information. Not open to students who have received credit for 73-100. While there are no calculus pre-requisites for this course, students are encouraged to enroll in 73-102 after they've passed 21-111. (Lecture, 2 hours; Recitation, 1 hour).

73-103 Principles of Macroeconomics

All Semesters: 9 units

A one-semester course that teaches the fundamentals of macroeconomics. Students will learn how macroeconomic analysis can explain national economic activity and how government intervention might stabilize an economy. Topics include: defining and measuring national wealth, economic growth, credit markets, unemployment, interest rates, inflation, and the monetary system. Additional emphasis will be paid to: long-term economic development, political economy, financial crises and topics that are central to contemporary macroeconomic debates such as the impact of technological change, migration, and trade on the macroeconomy. Students will access macroeconomic databases, and then use basic statistics to describe and isolate empirical patterns in macro-data. Not open to students who have received credit for 73-100. (Lecture, 2 hours; Recitation, 1 hour). Prerequisite: 73-102 Min. grade C

73-104 Principles of Microeconomics Accelerated

Intermittent: 9 units

This course is a rigorous introduction to microeconomic principles and how to think like an economist. The students are expected to have a successful, prior exposure to fundamental concepts and therefore, the course is at a faster pace than its sister course, 73102, and covers additional topics. The questions typically take the form: What is the optimal consumption pattern for me as an individual? What is the profit maximizing pattern of labor and capital goods for a firm? When do we want businesses to go bust? Should the government fund student tuition? How can firms hire the best match for them? What kind of informational asymmetries exist in double-sided markets? It's my hope that the students start to think about everyday questions from an economic lens: Why were cars so hard to find during the pandemic? Is Uber surge pricing just a rip-off? Is illegal streaming bad for consumers? Throughout the semester, we will build a toolkit to allow us to understand how these decisions interact and explain market successes, market failures, and the role of the third parties in the marketplace. Some later topics include credible threats, commitment problems, and the strategic use of information. Knowledge of basic calculus as covered in 21-111 would be helpful for the students. Only students with an AP Microeconomics Exam score of 4 or 5 and qualifying IB/Cambridge Economics exam scores are eligible to enroll in this course. Students without exam credit should enroll in 73-102 Principles of Microeconomics.

73-111 Internship I

All Semesters

By permission of the Undergraduate Economics Program.

73-112 Internship II

All Semesters: 3 units

The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-113 Internship III

All Semesters: 3 units

The goal of this course is for you to reflect critically and constructively on your internship and to help you identify a path that will allow you to build on your internship experiences. By permission of the Undergraduate Economics Program. Open only to declared Economics, Economics and Mathematical Sciences, Economics and Politics, and Economics and Statistics majors.

73-155 Markets, Models, and Math

Spring: 9 units

The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws.

73-158 Markets, Models, and Math

Spring: 9 units

The Markets, Models and Math (M3) course is designed to allow students to reflect on the thought processes that drive science, viewed through the lens of economics. While the economics focus will highlight the way economists use data and models to understand the economic phenomena we see in the real world, the course is also designed to add depth of understanding for students who major in some other discipline, for the simple reason that the things economists study touch on all aspects of human existence, whether it is understanding the cost-benefit trade-offs in architectural design, in the engineering of new products or production technologies, or understanding the grand arc of political discourse in history or the way it has shaped our laws. The course is also meant to introduce, in an intuitive way, the kinds of mathematical tools and reasoning that economists use, what the economic historian Philip Mirowski has called "the unreasonable efficacy of mathematics in economic analysis".

Prerequisites: 21-111 and 73-102 Min. grade C

73-199 Experiential Learning in Business and Economics

All Semesters: 3 units

Students will collaborate to create an economic newsletter called "Southwestern PA Economy in a Snapshot," a regional version of the well-known national version produced by the New York Fed (https://www.newyorkfed.org/medialibrary/media/research/snapshot/snapshot_january2021.pdf?la=en). The newsletter will lay the groundwork for a regular online publication produced by Carnegie Mellon Economics, a combination of data analysis/visualization and economic commentary. The ultimate goal is for the newsletter to be a to-go economics document for policy makers and business leaders in Pittsburgh and the surrounding region. Students will use a combination of data science skills, computer programming skills, and a basic knowledge of the relevant economic data. They will produce a professional, co-authored report that will serve as a valuable resume item for future career prospects. They will form small teams, each of which will create an Economic Commentary that uses the newsletter's data to provide analysis of a contemporary economic issue that is important to the Pittsburgh region. During the tenure of the course, students will also acquire new skills in computer programming, data analysis and economics. The course will "contribute to a broader body of knowledge" by obtaining, organizing and publicizing regional economic data where no such product currently exists. It will "identify and develop skills needed to approach and tackle a practical problem or issue." That is, students will take skills obtained in the single pre-req course (Principles of Macroeconomics) and combine them with skills that almost all 1st year students take in data analysis and produce a professional piece of economic analysis. They will see how their academic education can be applied in way that this useful to business people and policy makers.

Prerequisite: 73-102 Min. grade C

73-230 Intermediate Microeconomics

Fall and Spring: 9 units

This course builds on the Principles of Economics course. It focuses on the following topics: theory of the consumer, theory of the producer, perfectly competitive market equilibrium, imperfect competition, and market failures due to asymmetric information such as adverse selection and moral hazard. (Lecture, 3 hours; Recitation, 1 hour).

Prerequisites: (21-256 or 21-268 or 21-269 or 21-259) and (73-102 Min. grade C or 73-100 Min. grade C)

73-240 Intermediate Macroeconomics

Fall and Spring: 9 units

Through macroeconomic models built upon microeconomic foundations, insights are developed into economic growth processes and business cycles. Topics include aggregation and measurement, national income, business cycle measurement, economic welfare theorems and social inefficiencies, the effect of government fiscal policy upon employment and productivity, and the relationship between investment, interest rates and economic growth. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-256 and 73-100 Min. grade C) or (21-256 and 73-102 Min. grade C and 73-103 Min. grade C) or (21-259 and 73-100 Min. grade C) or (73-102 Min. grade C and 73-103 Min. grade C and 21-259)

73-255 Independent Study in Economics

Fall and Spring

The Independent Study course in economics allows students to pursue their own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor; the project proposal must be approved by an Undergraduate Economics Program staff member. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: 21-120 and 73-160 Min. grade C

73-258 Developing Blockchain Use Case

Intermittent: 6 units

Blockchains, or distributed ledger and consensus technologies, hold tremendous promise for improving markets and organically handling private, secure data. As CMU develops its own blockchain and token and #8212;-CMU Coin and #8212;-a central concern is to determine the set of applications that such technology would be most useful for. This course is designed for students to propose and, potentially, develop applications or use cases for a campus blockchain. <http://tinyurl.com/cmucoincourse> (<http://tinyurl.com/cmucoincourse/>) The course begins with a brief introduction to blockchain using Bitcoin as an example of a blockchain protocol. We will examine the market failure Bitcoin was intended to resolve as well as the role of cryptography and distributed systems in enabling this new technology to create societal value. The course will go on to discuss the boundaries of the role of cryptography in blockchain. Next, we will use these tools to evaluate existing, real-world blockchain use cases with an eye towards developing our own applications of these emerging technologies. Along the way, we will learn practical development skills in distributed ledger technologies to understand blockchain programming and application development. Finally, students will propose their own blockchain use cases for CMU's own proprietary blockchain. No formal prerequisites, but familiarity with programming is highly recommended.

73-265 Economics and Data Science

All Semesters: 9 units

This course is at the intersection of economic analysis, computing and statistics. It develops foundational skills in these areas and provides students with hands-on experience in identifying, analyzing and solving real-world data challenges in economics and business. Students will learn the basics of database and data manipulation, how to visualize, present and interpret data related to economic and business activity by employing statistics and statistical analysis, machine learning, visualization techniques. Students will also be taught a programming language suitable for data science/analysis. Databases will include leading economic indicators; emerging market country indicators; bond and equity returns; exchange rates; stock options; education and income by zip code; sales data; innovation diffusion; experimental and survey data and many others. Applications will include analyzing the effectiveness of different Internet pricing strategies on firm sales, the impact of taking online classes on a worker's earnings, the relationship between regional employment and trade policies; constructing investment risk indices for emerging markets; predicting employee productivity with machine learning tools; assessing health (sleep and exercise) improvements associated with wearable technologies (e.g. FitBit). Additionally, the course will provide students with communication skills to effectively describe their findings for technical and non-technical audiences. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (70-207 or 36-247 or 36-225 or 36-220 or 36-219 or 36-218 or 36-217 or 36-207 or 36-202 or 36-201 or 36-200 or 21-325 or 15-259) and 73-102 Min. grade C

73-270 Professional Communication for Economists

Fall and Spring: 9 units

A writing course specifically designed for second-year and third-year Economics majors and additional majors. Students gain experience with technical writing techniques and skills needed for both their eventual professional careers. The course emphasizes both individual and group projects. (Seminar, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (76-108 or 76-107 or 76-106 or 76-102 or 76-101) and 73-102 Min. grade C and 73-103 Min. grade C

73-274 Econometrics I

Spring: 9 units

Data tools are important in guiding decisions and strategies for individuals, businesses, and policymakers. This course will prepare you for data-driven decision making, providing both theoretical backgrounds and empirical illustrations of the techniques that are necessary to cope with real-world (imperfect) data. Specifically, the course covers tools and methods for estimating economic relationships, testing economic theories, and evaluating business and government policy. This course builds on either of the two Statistical Reasoning courses (36-200/201) and the Economics and Data Science course (73-265), and it sets underpinnings for Econometrics II (73-275) for more advanced tools and insights for business and economics data analyses. Students pursuing the ECOMTH or MTHECO degrees may enroll in 73-274 after the completion of 36-225. Minimum grade of "C" required in all economics and statistics pre-requisite courses.

Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and 73-265 Min. grade C and (73-240 Min. grade C or 73-230 Min. grade C)

73-315 Market Design

Intermittent: 9 units

In this course, we consider the design of various market mechanisms. We learn the typical causes of market failures and why we need to design new markets. For each topic, we start with a case study of a problem, develop a theory to address it, and consider its possible solutions. The class is roughly divided into three parts: matching, auctions, and further topics. In the first part, we study markets where there is no money and no prices (matching markets). Instead, we have people preferences over possible matching outcomes. Examples include placing doctors in residency positions, assigning students to schools, and assigning kidneys to transplant patients. We will learn algorithms that have desirable theoretical properties and are often used in practice. In the second part, we consider the problem of allocating of single or multiple goods (a house, a painting, or the rights to a natural resource such as oil or timber) using auctions. We discuss how different types of auctions work in theory and practice. We will look at the auctions used in financial markets to sell treasury bills, the auctions used by Google, Microsoft and Facebook to sell advertising, and the auctions used by governments to sell radio spectrum licenses. In the third part, we consider further important topics of market design. We will look into problems of high-frequency trading, digital markets, the allocation of refugees among European countries, and proposals to fix market for carbon pollution permits. An important goal of the course is to show how recent achievements of game theory and mechanism design lead to important practical applications and to inspire you to use these ideas in your life and workplace. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and 73-230 Min. grade C

73-327 Advanced Topics In Macroeconomics And Real Business Cycles

Intermittent: 9 units

For analysts and decision makers in a variety of positions, such as business managers and government policy makers, a thorough understanding of the economy as a whole helps to make well-informed decisions. Examples of important knowledge about the economy are its sources of growth, the main impulses that cause the economy to fluctuate over time and enter into booms and recessions, the way in which these impulses propagate over time, and the state of the economy in general. The main objective of this course is to lay the foundation for such an understanding and present a framework within which we can (and will) evaluate a variety of aggregate phenomena. Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-256 or 21-259 or 21-268) and 73-240 Min. grade C

73-328 Health Economics

Fall: 12 units

This course will teach the student to use economic analysis to understand critical issues in health care and health policy. We will address issues such as the following: 1. What factors best explain the level and rate of growth of U.S. health expenditures? 2. Does the recent high rate of growth of U.S. health care expenditures make U.S. firms less competitive in international markets? 3. What are some of the likely consequences (intended and unintended) of the proposed reforms to Medicare? 4. Can physicians induce demand for their services? 5. What are the impacts of managed care on the health care system? 6. Do strong affiliations between physicians and health plans hurt competition? (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Junior standing required.

Prerequisites: 21-120 and 73-102 Min. grade C

73-332 Political Economy

Spring: 9 units

The Political Economy course looks at how groups within society organize for self-governance. The course will begin with an overview of the ways groups of individuals organize for collective action by examining different types of political institutions, the role these institutions play in different contexts, and the economic and strategic micro-foundations that give rise to these institutions. We will then examine the empirical evidence supporting this taxonomy, leading to a more detailed consideration of institutions that moderate social conflicts. The next part of the course examines basic results in social choice theory: the Condorcet paradox, Arrow's Impossibility Theorem, majority rule, median voter theories, and modern treatments of probabilistic voting models that allow for strategic behavior, misrepresentation of preferences, and policy manipulation. From this basis for understanding collective choice mechanisms, we will then examine how institutions foster cooperation, looking in detail at problems of public goods allocation, redistribution of income, the organization of clubs - interest groups and lobbying associations and #8212; in the private sector, and the organization of legislative activities in the public sector. In our examination of voting and electoral mechanisms, we will look at practical applications of the theory to problems of gerrymandering, voter suppression, and propaganda that feature prominently in contemporary political discourse.

Prerequisites: (73-230 Min. grade C or 73-160 Min. grade C) and (36-201 or 36-200)

73-337 Business of Blockchain

Intermittent: 9 units

Economics and business strategy is fundamental for the design and development of blockchain use cases. This course will introduce students to foundational economic concepts to help them understand the role cryptocurrencies play in securing blockchains, how different "tokenomics" models impact cryptocurrency prices, the different means to create liquidity or resolve illiquidity in decentralized finance (DeFi) applications such as stablecoins, collateralized-lending, yield farming, or automated market making, the roles of Central Bank Digital Currencies, as well as models to evaluate the value-added of blockchain-based versus traditional business propositions. This course may use third-party course material that is not available for individual purchase from the publisher. If so, the third-party course material will be secured and provided by the Tepper School to students enrolled in the course, and students enrolled in the course will be required to pay to the University the associated additional course materials fee for the third-party course material provided. The amount of the course materials fee is dependent on the University's cost of the particular materials provided, and typically ranges from \$13 to \$75.

Prerequisites: 73-103 Min. grade C and 73-102 Min. grade C

73-338 Financial Crises and Risk

Fall: 9 units

This course provides an in-depth examination of the causes of financial crises as well as what governments can do to prevent them or at least reduce their cost. The course is designed to provide an understanding of individual attitudes towards risk and individual decision making about savings and investment under uncertainty, and to use this understanding to evaluate the various economic roles played by financial institutions in helping individuals manage risk, especially those roles which may lead to economic instability and crises. In addition, the course may cover bubbles and swindles, especially when these spillover to the broader macroeconomy; the role of information in banking in normal times and in bank runs; crisis resolution techniques; and the extensive history of attempts to improve regulation so as to reduce the frequency and cost of crises. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and 73-102 Min. grade C and 73-240 Min. grade C

73-341 Managing through Incentives

Intermittent: 9 units

We live in an exciting age of information and knowledge when inspiring employees within a firm becomes increasing important. Aligning the objectives of workers, managers, and owners by providing them with appropriate incentives becomes an emerging paradigm in the modern business world. In this course, we learn how to reason about incentives between managers and employees, between managers and owners, and within a team of co-workers. We cover a broad range of topics including objective and subjective performance measurements, relative performance evaluations, relational contracts, and executive compensation. The course relies on business case discussions, rigorous theoretical material, and numerous class activities. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-259 or 21-268 or 21-269 or 21-256) and (36-217 or 36-225 or 36-218 or 36-219 or 36-220 or 36-200 or 36-207 or 70-207 or 36-202 or 36-201) and 73-230 Min. grade C

73-347 Game Theory Applications for Economics and Business

Fall: 9 units

An introduction to the theory of non-cooperative games with an emphasis on economic applications. After an initial examination of two-person, zero-sum games, the notion of a Nash equilibrium in an n-person, non-cooperative game is considered. Existence of and refinements to the equilibrium concept are discussed in the context of both normal and extensive form games. Economic applications may include various topics, including Cournot and Bertrand oligopoly models, general competitive exchange equilibrium, and free rider problems. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

73-348 Behavioral Economics

Spring: 9 units

This course introduces students to behavioral economics which is a subfield of economics that incorporates insights from other social sciences, such as psychology, into economic models and aims to explain the anomalies challenging some of the classical economic models. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (36-200 or 36-225 or 36-207 or 36-217 or 70-207) and 21-120 and (73-102 Min. grade C or 73-100 Min. grade C)

73-352 Public Economics

Fall: 9 units

In this course, students analyze the role of governments in market economies and their impact on the behavior and welfare of citizens. Reasons for government intervention in markets are examined in light of some of the economic challenges faced by modern societies in an increasingly globalized marketplace. Topics include: taxation and expenditure policies, externalities and market failure, social security, public assistance and income redistribution programs. There will also be some coverage of the role of local governments in the economy with respect to such issues as crime, urban development and education. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-256 or 21-259 or 21-269 or 21-268) and 73-230 Min. grade C

73-353 Financial Regulation in the Digital Age

Spring: 9 units

The financial crisis and the digitalization of the financial markets have focused attention on the role of regulation for our financial system and the broader economy in recent years. Among the settings that are especially important in the digital economy are electronic trading, big data, algorithms, robo investing, winner-take-all economics, securities offerings, property rights and cyber assets. The course will address the foundations of regulation ("why regulate?") from various perspectives within a market economy, highlighting the sources of "market failure" (such as externalities, adverse selection, and natural monopoly) and potential remedies (such as disclosure, taxes and fees, antitrust prohibitions, privacy requirements, price regulation and guarantees). The conflicting goals among regulators (and why we have multiple regulators) and their impact on the meaning of regulation will be considered along with regulatory competition/arbitrage. Portions of the course will tackle relatively broad questions such as: Why regulate? Why could it be beneficial to restrict permitted algorithms? Are our markets rigged? How suitable are antitrust remedies in the digital era? What is the law of unintended consequences? What is the objective of a policy advocate? Are regulators and regulatory policies a systemic risk? How can regulators enhance the predictability and credibility of their policies? Should we bar insider trading? Should regulations be determined and motivated based upon cost-benefit analysis? How can we evaluate the success or failure of particular regulations and whether they have achieved their objectives? To what extent did the Dodd-Frank Act ensure financial stability?(Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C

73-359 Benefit-Cost Analysis

Intermittent: 9 units

The evaluation of public private sector projects. The theory of benefit-cost analysis and related techniques, such as cost-effectiveness analysis. Attention is given to such issues as valuing goods and services that are not normally traded in the marketplace (e.g., the value of an individual's life) and the social rate of discount. Applications are considered in detail. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (73-102 Min. grade C or 73-100 Min. grade C) and (36-225 or 36-202 or 36-200 or 36-220 or 36-217 or 36-207 or 70-207)

73-365 Firms, Market Structures, and Strategy

Fall: 9 units

This course is concerned with the economic analysis of industrial markets that are not perfectly competitive. The effects of imperfect competition on firms' decisions (pricing, location, advertising, research and development, among others) are reviewed. Implications of these effects in terms of public policy are also discussed from a variety of perspectives. Finally, applications to actual markets are considered. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-269 or 21-259 or 21-256 or 21-268) and 73-230 Min. grade C

73-366 Designing the Digital Economy

Spring: 9 units

This class analyzes the economics of e-commerce and technology. It will identify the critical features that differentiate the technology firms from traditional industries, and examine the implications for business strategy. The class will discuss topics such as network effects, switching costs, and platform markets. To complement the economic theory, we will also consider a case study of a firm each week. These have three aims: to provide applications for the concepts developed in the lectures; to inform you about different industries; and to help develop your written, rhetorical and presentation skills. Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: (21-268 or 21-269 or 21-259 or 21-256) and 73-230 Min. grade C and (36-208 or 36-220 or 36-226 or 70-208 or 73-265 Min. grade C or 73-274 Min. grade C or 73-374 Min. grade C or 73-407 Min. grade C or 36-202)

73-369 Islamic Economics

Intermittent: 9 units

This course is designed to introduce students to the basics of Islamic Finance. The course will start with an analysis of the Shariah rules that define Islamic Finance. Students will then look at the main investment structures and map these against the traditional conventional banking products. The course wraps up with a critique of complex project finance structures through a Shariah compliance lens to identify the gaps between theory and practice.

73-374 Econometrics II

Fall: 9 units

The material covered in this course extends from the material covered in Econometrics I (73-274). The course will include both the theory behind the methods and a hands-on analysis of actual data, providing students the tools for both research and industry jobs. Theories and methodologies covered will include: nonlinear regression models, qualitative response regression models, panel data estimators, simultaneous-equation models, and time series. (Lecture, 3 hours; Recitation, 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses. Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and 73-230 Min. grade C and 73-274 Min. grade C

73-395 Independent Study in Economics

Fall and Spring

The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses. Prerequisites: (21-269 or 21-268 or 21-259 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C)

73-408 Law and Economics

Intermittent: 9 units

This course will provide a broad overview of the scholarly field known as "law and economics." The focus will be on how legal rules and institutions can correct market failures. We will discuss the economic function of contracts and, when contracts fail or are not feasible, the role of legal remedies to resolve disputes. We will also discuss at some length the choice between encouraging private parties to initiate legal actions to correct externalities and governmental actors, such as regulatory authorities. Extensive attention will be given to the economics of litigation, and to how private incentives to bring lawsuits differ from the social value of litigation. The economic motive to commit crimes, and the optimal governmental response to crime, will be studied in depth. Specific topics within the preceding broad themes include: the Coase Theorem; the tradeoff between the certainty and severity of punishment; the choice between ex ante and ex post sanctions; negligence versus strict liability; property rules; remedies for breach of contract; and the American rule versus the English rule for allocating litigation costs. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses. Prerequisites: 21-120 and 73-102 Min. grade C

73-415 Data Driven Business and Public Policy Decision Making

Intermittent: 9 units

In this course students will learn to leverage data to inform business and policy decisions. The course will teach students various methods for data description, including techniques of data visualization and statistical techniques. Students will learn how to assess the precision of estimation techniques. The final part of the course covers examples taken from epidemiology, economics, business and public policy. (Lecture, 3 hours; Recitation: 1 hour). Minimum grade of "C" required in all economics and statistics pre-requisite courses.

Prerequisites: (21-268 or 21-259 or 21-269 or 21-256) and 73-230 Min. grade C and 73-265 Min. grade C

73-421 Emerging Markets

Fall: 9 units

The goal of the course is to study the economic and institutional forces that spur or hinder business activity and growth in emerging economies. The course is designed to provide both quantitative and theoretical foundations for the study of emerging markets. On the quantitative side, the course will introduce students to the empirical analysis of the growth forces and obstacles facing emerging markets by providing numerous hands-on opportunities using real-world data. On the theory side, the course will provide an overview of fiscal, trade and exchange rate policies adopted in emerging economies. The course will focus on successful emerging economies such as India, China, S. Korea and Ireland with broader lessons and comparisons drawn from developed countries. The course will look at distressed economies, such as North Korea and Venezuela analyzing the challenges and opportunities faced by these developing nations today. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (36-207 or 36-200 or 36-202 or 70-207 or 15-259) and 73-102 Min. grade C and 73-103 Min. grade C

73-423 Forecasting for Economics and Business

Spring: 9 units

Governments forecast economic indicators (e.g., GDP, job growth, etc.); businesses forecast sales; portfolio managers forecast asset return; the list goes on. Accurate forecasts are critical to robust organizational decision-making. This course will introduce students to modern methods for forecasting in economic and business applications. Topics covered include Bayesian, statistical, and online learning approaches to forecast construction and assessment, univariate and multivariate time series models and algorithms, and principled combination of multiple methods and data sources along with subject matter expertise to improve performance. Methods will be motivated by applications in macroeconomics, technology, marketing, and finance, with cases drawn from forecasting processes in a variety of business and government organizations. Students will implement forecasting methods in R, including in a real data forecasting competition. Prerequisites: (21-268 or 21-259 or 21-256 or 21-269) and (73-230 Min. grade C or 73-240 Min. grade C or 73-274 Min. grade C)

73-427 Sustainability, Energy, and Environmental Economics

Fall: 9 units

Topics related to sustainability and the environment are increasingly important to businesses, policymakers, and the general public. This course applies the tools of economic analysis to the problems of environmental protection, natural resource management, and energy production and use. The course will begin by introducing students to how an economist approaches problems of market failure commonly found in environmental contexts. Next, we will explore models that characterize solutions to such environmental issues. We will then address questions regarding measurement, policy design, and, finally, we will apply the tools that we have developed during the semester to the problems of climate change, and the optimal management of non-renewable resources. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (73-102 Min. grade C or 73-100 Min. grade C) and (36-207 or 36-202 or 36-200 or 36-217 or 36-225 or 70-207 or 36-220)

73-469 Global Electronic Markets: Economics and the Internet

Fall: 9 units

The information revolution brought about by the Internet is having a dramatic impact on the organization of economic activity. Long-term contractual relationships that once governed corporate procurement are being dismantled as manufacturers use the Internet to market directly to the public. New transportation networks that used to simply move goods from point A to point B are evolving into dynamic inventory pipelines that allow manufacturers to track and even reroute shipments in real time. At the same time, individuals are making use of sophisticated search engines to comparison shop at a scale that would have been physically exhausting even five years ago. We will use the basic tools of economic analysis to understand how and why the changes in information technology are reshaping the economic landscape. (Lecture, 3 hours). Minimum grade standard of "C" applies only to economics courses.

Prerequisites: (21-268 or 21-256 or 21-259 or 21-269) and (73-230 Min. grade C or 73-160 Min. grade C)

73-476 American Economic History

Fall: 9 units

The study of economic history provides important perspective on current economic institutions and policies. A failure to understand the historical evolution of economic institutions or the variety of past economic experience is perhaps the worst shortcoming of many economists. The study of economic history provides an opportunity to test currently fashionable theories against data different from those used in their construction. In fact, this is a course in applied economics. The theories developed in the intermediate courses will be applied to episodes from the past in ways that increase understanding both of the specific historical episodes considered and the economic theories employed. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: 21-120 and (73-160 Min. grade C or 73-230 Min. grade C)

73-495 Advanced Independent Study in Economics

All Semesters

The Independent Study course in economics allows the student to pursue his or her own research interests in any of a variety of topics in economics. A typical independent study course involves a semester long project under the supervision of an appropriate faculty advisor. The nature and scope of the project are determined by the student and faculty advisor. Minimum grade standard of "C" applies only to economics courses.

Prerequisites: (21-259 or 21-268 or 21-269 or 21-256) and (73-230 Min. grade C or 73-240 Min. grade C)

Course Website: <http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics> (<http://tepper.cmu.edu/prospective-students/course-page/73495/advanced-independent-study-in-economics/>)

73-497 Senior Project

Fall: 9 units

A fourth-year project course, open only to Economics primary and additional majors with Senior standing. The senior project is a capstone course in economics. The purpose of the course is to showcase the analytical and quantitative skills that you have acquired as an undergraduate at Carnegie Mellon. The course project should reflect some independent applied research that is genuinely your own work. Thus a "book report" or a "literature review" are not sufficient exercises to satisfy this requirement. The following research approaches are acceptable for the research project: an empirical study based on a data set that you put together, an experimental study based on an experiment that you conducted, an analysis of survey data based on a survey that you conducted, a theoretical analysis based on a model that you have developed, based on your own algorithm. Students who write an honor thesis are exempted from this class. (Lecture, 3 hours). Minimum grade of "C" required in all economics pre-requisite courses.

Prerequisites: (21-269 or 21-268 or 21-256 or 21-259) and (73-407 Min. grade C or 73-374 Min. grade C or 73-274 Min. grade C or 73-265 Min. grade C or 36-226 or 36-303) and 73-230 Min. grade C and 73-240 Min. grade C

73-500 Tepper College Honors Thesis I

Fall and Spring

Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses. Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and (73-265 Min. grade C or 73-274 Min. grade C or 36-226 Min. grade C) and 73-230 Min. grade C and 73-240 Min. grade C

73-501 Tepper College Honors Thesis II

Fall and Spring

Economics majors with outstanding academic records and intellectual promise will be given the opportunity to undertake original research under the direction of individual faculty members. Research topics are selected by students and approved by faculty. Prerequisites include: Senior standing in the Economics Program and permission of the Economics faculty. Minimum grade of "C" required in all economics and statistics pre-requisite courses, and a minimum grade of "B" required in Tepper College Honors Thesis I. Prerequisites: (21-256 or 21-259 or 21-268 or 21-269) and 73-230 Min. grade C and 73-240 Min. grade C and 73-500 Min. grade B and (73-265 Min. grade C or 73-374 Min. grade C)

Carnegie Mellon University in Qatar

Michael Trick, Dean
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Undergraduate Programs Office: CMB 1101
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Carnegie Mellon University in Qatar is Carnegie Mellon's first and only undergraduate branch campus. Since 2004, it exists as part of a collaborative effort with the Qatar Foundation to bring outstanding American educational programs to the Middle East.

Degree Offerings

Carnegie Mellon University in Qatar offers four academic programs: Biological Sciences (p. 590), Business Administration (p. 698), Computer Science (p. 698), and Information Systems (<http://coursecatalog.web.cmu.edu/schools-colleges/dietrichcollegeofhumanitiesandsocialsciences/informationssystemsf/#curriculumtextcontainer>). To examine the requirements for those degrees, see their respective main campus college sections elsewhere in the Undergraduate Catalog. The purpose of this section is to describe the CMU-Q policies that are independent from those of the Pittsburgh campus and outline procedures that are common to students in all programs in Qatar.

Major Sample Schedules

Sample schedules for how CMU-Q students normally track through the academic programs can be found on the CMU-Q website as follows:

- Biological Sciences (<http://www.qatar.cmu.edu/curriculum-bs/>)
- Business Administration (<http://www.qatar.cmu.edu/curriculum-ba/>)
- Computer Science (<http://www.qatar.cmu.edu/curriculum-cs/>)
- Information Systems (<https://www.qatar.cmu.edu/academics-research/academics/information-systems/>)

Business Administration Concentrations

The concentration allows students to gain knowledge and expertise in a particular area of business practice. The concentration coursework prepares students with the knowledge and skills for their career pursuits. Completing a concentration is part of the degree requirements. Students are encouraged to declare their concentration by the end of their sophomore year.

Courses taken to meet concentration requirements are not allowed to double count toward any other BA degree requirements, including the minor requirement. The following concentrations may be completed at Carnegie Mellon University in Qatar:

- Accounting
- Business Analytics and Technologies
- Entrepreneurship
- Finance
- Global Economics and Business
- Marketing Management
- Operations Management
- Strategic Management

Information Systems Concentrations

As an Information Systems major, you will select a focused concentration to provide a deep dive into a subject that interests you consisting of a minimum of three 9 unit courses and a 12 unit project or research course (39 units total). Currently approved IS Concentrations on the Qatar campus include:

- Information Security & Privacy

The Information Security & Privacy concentration is designed to expose students to the key technical, process, and policy aspects related to information security and associated privacy concerns. The student who completes this concentration will have a solid foundation in the area and will be prepared to continue developing expertise through graduate school or their professional career.

- Data Science

The Data Science concentration is designed to capitalize on the continuously expanding quantity of data generated through our interconnected information systems and prepares the student to understand how to store, process, retrieve, and analyze data to derive insights and improve decision making for individuals, organizations, and society. The foundation developed in this concentration prepares the graduate to assist organizations to capitalize on the data they generate as well as to support research projects either as a graduate student or within their chosen profession.

- Digitization

The Digitization concentration is designed to prepare the student to understand and effectively innovate with information systems to support entrepreneurship, organizations, or society. The graduate with this concentration will often find themselves working in a larger organization or creating new organizations that capitalize on the benefits of information and information systems.

In addition to the approved concentrations, a student may choose to instead complete an approved minor or second major, or work with their advisor to develop a plan for an independent concentration.

Additional Major in Information Systems

Students who elect Information Systems as an additional major must fulfill all Information Systems degree requirements, including prerequisites, Professional Core, Disciplinary Core, and Concentration Area requirements. With respect to double-counting courses, the program will allow up to two courses to count between the additional major and a primary major. Students should begin planning their additional major as early as possible, as the Information Systems core courses are sequential, and are often the constraining resource for completion of the major.

Only one course can be double-counted between the Information Systems major and a minor.

Minors

In addition to the major degree programs, Carnegie Mellon also offers a number of minors. Minors typically consist of six courses that provide the student with substantial exposure to the core of that academic discipline. As with the major programs, the requirements of these minors are set by their respective departments on the main campus:

- Arabic Studies (advisor: Ezzohra Moufid) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Biological Sciences (advisor: (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>) Mohamed Bouaouina (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Business Administration (advisor: Serkan Akguc) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Cognitive Neuroscience (advisor: Jennifer Bruder) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Computational Biology (advisor: Giselle Reis) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Computer Science (advisor: Giselle Reis) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Economics (advisor: Agustin Indaco) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Global Systems and Management (advisor: Daniel Phelps) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- History (advisor: Ben Reilly) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Information Systems (advisor: Daniel Phelps) [only offered in Qatar] (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Mathematical Sciences (advisor: Hasan Demirkoparan) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Media and Politics (advisor: Kira Dreher) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)

- Multidisciplinary Energy Studies (advisor: Serkan Akguc) [only offered in Qatar] (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Neuroscience (advisor: Nesrine Affara) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Professional Writing (advisor: Thomas Mitchell) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Psychology (advisor: Jennifer Bruder) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)
- Tech Entrepreneurship (advisor: Nui Vatanasakdakul) (<https://scotty.qatar.cmu.edu/academic-services/minor-information/>)

Academic Standards and Actions

Academic Standards

Carnegie Mellon University in Qatar complies with common University policies unless otherwise noted. The curriculum requirements for the Biological Sciences, Business Administration, Computer Science and Computational Biology, and Information Systems majors are set by the respective departments of the Mellon College of Science, Tepper School of Business, the School of Computer Science, and the Dietrich College of Humanities and Social Sciences and the Heinz College of Information Systems and Public Policy on the main campus. At the university level, the same academic standards, policies, and actions apply to all programs at CMU-Q as at the Pittsburgh campus.

Graduation Requirements

Residency

Candidates for a Bachelor's degree must complete a minimum of four semesters of full-time study, or equivalent part-time study, comprising at least 180 units of coursework at Carnegie Mellon.

Cumulative QPA

To be eligible to graduate, undergraduate students must complete all course requirements for their program with a cumulative Quality Point Average of at least 2.0 for all courses taken. For undergraduate students who enrolled at Carnegie Mellon as first-year students and whose first-year grades cause the cumulative QPA to fall below 2.0, this requirement is modified to be a cumulative QPA of at least 2.0 for all courses taken after the first year. Note, however, the cumulative QPA that appears on students' final transcript will be calculated based on all grades in all courses taken, including the first year. Some programs may have additional QPA requirements in order to graduate. Students are encouraged to confirm all graduation requirements with their academic advisor.

University Honors

Students maintaining a cumulative QPA of at least 3.5 after seven semesters of full-time enrollment (consecutive or otherwise) or raising their QPA to 3.5 upon completing their graduation requirements in their final semester will graduate with University Honors.

Dean's List

Students earn Dean's List recognition in a given semester by achieving one of two minimum standards. They must either 1) earn a semester QPA of 3.75 or higher (while taking at least 36 factorable units and receiving no incomplete grades), or 2) earn a semester QPA of 3.50 or higher (while taking at least 45 factorable units and receiving no incomplete grades). The CMU-Q Dean's List is calculated uniformly for all students across all majors and may differ from criteria followed for these majors on the Pittsburgh campus, where the criteria vary across colleges.

Academic Actions

Academic Actions are a part of a process designed to help students who are not meeting standards for satisfactory academic progress be successful. Students will be informed by a letter from the Senior Associate Dean for Education if an academic action has been taken in their regard. The letter will identify individuals and resources that can help them address barriers to their success. Academic Actions may be taken for students carrying either a full-time course load (defined as 36 or more units) or a part-time course load (defined as fewer than 36 units).

Failure to Meet Minimum Standards

Academic Actions may be taken if students fail to meet minimum standards toward their degree, defined as follows:

- First-year students: a semester QPA of at least 1.75.
- Beyond the first year: a semester QPA and a cumulative QPA (excluding the first year) of at least 2.0.
- Students who begin a semester enrolled in 36 or more units and later drop below 36 units are subject to academic actions regardless of their semester QPA.

Probation

Probation occurs when a student's semester record fails to meet the minimum standards described above. The term of a probation is one semester as a full-time student. Students will return to good academic standing if they complete at least 36 units under the following circumstances:

- For a first-year student, probation is removed at the end of the second semester if the second semester's QPA is 1.75 or above.
- For students in the third or subsequent semesters, probation is removed if they raise their cumulative QPA above 2.00, and achieve a semester QPA of 2.0 or higher (excluding the first year).

Probation Continued

Occasionally, a student's probation may be continued if the student's cumulative record does not meet minimum standards, but his or her semester record suggests that the student may do so by the end of the next semester. This action is normally taken only when a student's semester QPA is above 2.0 but their cumulative QPA is not yet above 2.0.

Suspension

A student who fails to meet the minimum standards described above at the end of the probation semester may be suspended.

- A first-year student may be suspended if the QPA from each semester is below 1.75.
- A student in the third or subsequent semester of study may be suspended if the semester QPA or the cumulative QPA (excluding the first year) is below 2.00 for two consecutive semesters.

Suspension is typically for a minimum of one year. While on academic suspension, students are considered to be on a mandatory "leave of absence" and are governed by College and University policies concerning leaves of absence (<https://www.cmu.edu/policies/student-and-student-life/student-leave.html>). Per university policy, students on suspension may not attend classes, live in university-related housing, or have on-campus employment.

At the end of their suspension period, the student may petition to return to CMU-Q by:

- submitting a petition to Return from Leave of Absence form to the Enrollment Services Manager in Qatar;
- providing evidence in writing to the Senior Associate Dean for Education that they have fulfilled return conditions specified in the letter informing them of their suspension (if any) and have taken convincing steps to ameliorate the cause of the suspension. The student must demonstrate that they are better prepared to perform above the minimum standards for graduation than before they were suspended; and
- resolving any outstanding financial obligations.

Students will be notified by the University Registrar's Office once their petition has been approved and their enrollment status has been updated to "eligible to enroll." Students coming back from suspension are placed on Probation for the semester of their return.

Drop

A student who fails to meet minimum standards at any point after returning from a suspension is subject to a drop action. A drop action is a permanent severance; the student is required to follow University procedures for departing from campus and may not enroll again in the future.

The typical progression of academic actions is Probation, Suspension, then Drop. Because the intent of all academic actions is to take measures that are in the student's best interest, the school may bypass one or more of these steps in an unusual case and suspend or drop a student without prior probation.

Other Regulations Affecting Student Status

Adding a Class

Students may add classes to their schedule under the following rules:

- a full-semester course through the first 10 class days of the semester.
- a half-semester (mini) course may be added through the first 5 class days of the half-semester when the course is offered.

Dropping/Withdrawing from a Class

Students may drop or withdraw from a class as prescribed by the university's policy for doing so: <https://www.cmu.edu/hub/registrar/course-changes/index.html> (<https://www.cmu.edu/hub/registrar/course-changes/>)

Course Overloads

A maximum load for a CMU-Q student is 51 units. In order to overload (i.e., take more than 51 units but no more than 63), a student must have attained a QPA of at least 3.0 in the previous semester, or have a cumulative QPA of 3.0. Approval by the student's advisor is required to upload up to the maximum (63 units). A student wishing to pursue more than 63 units must petition the Senior Associate Dean for Education to do so.

Non-Carnegie Mellon Courses

Carnegie Mellon University offers students the opportunity to take courses for credit through a cross-registration program and through the receipt of transfer credit from other accredited institutions. The Carnegie Mellon transcript will include information on such courses as follows:

- Carnegie Mellon courses and courses taken through the university's cross-registration program will have grades recorded on the transcript and be factored into the QPA.
- All other courses will be recorded on the transcript indicating where the course was taken, but no grade will be reported. Such courses will not be taken into account for academic actions, honors or QPA calculations.

Note: Suspended students may take courses elsewhere with prior approval; however, they will not receive transfer credit.

Cross Registration

Courses offered for cross-registration are those taken through an agreement with Texas A&M University at Qatar; Georgetown School of Foreign Service in Qatar; Northwestern University in Qatar; Virginia Commonwealth University in Qatar; and Weill Cornell Medical College in Qatar. Full-time students at Carnegie Mellon University in Qatar can take up to one class a semester at these schools. Cross-registration requires the completion of a cross-registration form with the appropriate signatures from the home and host institutions. Completion of the form does not guarantee a space in the requested course. The cross-registration agreement only applies during the regular academic year; normal course transfer rules apply in the summer.

Course Transfer

Students may receive credit for courses taken outside of Carnegie Mellon if they successfully petition the Senior Associate Dean for Education in advance for permission. Students must take these courses for a letter grade and instruction must be in English for non-language courses. Credit (but not the grade) will normally transfer for courses with a grade equivalent to at least a "B." The class's course description must be a close match to a Carnegie Mellon course or material covered in a range of Carnegie Mellon courses and from an accredited institution. Students may not receive credit for any courses taken on-line unless there is some safeguard to ensure that the actual student took the course (e.g., a proctored final taken under supervision at CMU-Q).

Students may not receive credit for more than five non-CMU courses during their undergraduate career as a Carnegie Mellon student. Classes taken prior to enrolling in Carnegie Mellon, during study abroad semesters, and as cross-registration with other Education City schools do not count toward the course transfer limit. All students must meet the University's residency requirement of completing at least 180 units of Carnegie Mellon coursework.

Campus Exchange and Transfer

Campus Exchange

CMU-Q and Pittsburgh students in good academic standing (not on Probation/Suspension) may study on the other campus for one semester on a space available basis and with the approval of both the home and host departments. Space constraints on both campuses may force programs

to limit the number of students who can exchange in any given semester.

CMU-Q students may study abroad for a second semester at another institution (not CMU Pittsburgh) if an appropriate additional study abroad opportunity arises and their academic advisor agrees.

Summer studies in Pittsburgh are not subject to any constraint other than not being on Suspension or Leave of Absence.

Transfer

Internally between majors at CMU-Q

Students may transfer between majors at CMU-Q on a space-available and academic performance basis. Students interested in transferring should consult with the Senior Associate Dean for Education and the Area Head of the new major. First-year students may not apply for transfer until they receive their spring mid-semester grades.

Between CMU-Q and Carnegie Mellon, Pittsburgh

Decisions about transfers to any major in Pittsburgh will be made by the receiving department in conjunction with the Vice-Provost for Education. Transfers are only possible under specific conditions and for study beginning in a fall semester. Students interested in transferring to a major in Pittsburgh the following academic year should consult with the Senior Associate Dean for Education in Qatar as early as possible in order to understand the conditions and process for applying.

Transfers to CMU-Q from other Universities

Transfer students from other universities must apply through the Admissions Office at Carnegie Mellon University in Qatar. The Admissions Office, the Senior Associate Dean for Education, and the Area Head for the desired program will determine if there is space available and if the student's past academic performance warrants admission.

Faculty

MOHAMMAD AAZAM, Assistant Teaching Professor, Information Systems; Carnegie Mellon, 2022-

IMAN ADEINAT, Associate Teaching Professor, Operations Management - Ph.D, University of New Orleans; Carnegie Mellon, 2021-

NESRINE AFFARA, Assistant Teaching Professor, Biological Sciences - Ph.D., Ohio State University; Carnegie Mellon, 2017-

SERKAN AKGUC, Associate Area Head, Business Administration; Assistant Teaching Professor, Finance - Ph.D., Temple University; Carnegie Mellon, 2017-

CHADI AOUN, Teaching Professor, Information Systems - Ph.D., University of New South Wales; Carnegie Mellon, 2014-

JOCELYN BELANGER, Associate Teaching Professor of Psychology, Carnegie Mellon, 2023-

HOUDA BOUAMOR, Associate Area Head, Information Systems; Associate Teaching Professor, Information Systems - Ph.D., Université Paris Sud; Carnegie Mellon, 2015-

MOHAMED BOUAOUINA, Associate Area Head, Biological Sciences; Associate Teaching Professor, Biological Sciences - Ph.D., Pierre and Marie Curie University; Carnegie Mellon, 2013-

JENNIFER BRUDER, Associate Dean for Research; Associate Teaching Professor, Psychology - Ph.D, University of Munich; Carnegie Mellon, 2017-

ANDRES MAURICIO CASTANO, Assistant Teaching Professor in Economics and Analytics, Carnegie Mellon, 2023-

ANIS CHARFI, Associate Teaching Professor, Information Systems - Ph.D., Technische Universität Darmstadt; Carnegie Mellon, 2015-

HASAN DEMIRKOPARAN, Co-Area Head, Art and Sciences; Teaching Professor, Mathematics - Ph.D., Michigan State University; Carnegie Mellon, 2005-

GIANNI DI CARO, Associate Teaching Professor, Computer Science - Ph.D., Université Libre de Bruxelles; Carnegie Mellon, 2016-

CRISTIAN DIMITRIU, Visiting Associate Professor, Philosophy - Ph.D, University of Toronto; Carnegie Mellon, 2022-

KIRA DREHER, Associate Dean for Diversity, Equity, Inclusion and Belonging; Assistant Teaching Professor, English - Ph.D., University of Minnesota; Carnegie Mellon, 2019-

LAYAN EL HAJJ, Associate Teaching Professor, Mathematics; Carnegie Mellon, 2023-

- HUSSEIN FADLALLAH, Assistant Teaching Professor of Management, Carnegie Mellon, 2023-
- MUHAMMAD FUAD FAROOQI, Area Head, Business Administration; Teaching Professor, Finance - Ph.D., Richard Ivey School of Business; Carnegie Mellon, 2013-
- SIMON FAULKNER, Assistant Teaching Professor, Chemistry - Ph.D., University College London; Carnegie Mellon, 2019-
- EDUARDO FEO FLUSHING, Assistant Teaching Professor, Computer Science; Carnegie Mellon, 2023-
- MADHAVI K. GANAPATHIRAJU, Visiting Associate Professor, Computational Biology - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2022-
- KI-WON HAAN, Assistant Teaching Professor of Organizational Behavior, Carnegie Mellon, 2023-
- MARIA PIA GOMEZ LAICH, Assistant Teaching Professor, English - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2018-
- SUSAN HAGAN, Associate Teaching Professor, Information Systems - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004-
- MAHER HAKIM, Distinguished Career Professor; Carnegie Mellon, 2022-
- MOHAMMAD HAMMOUD, Associate Teaching Professor, Computer Science - Ph.D., University of Pittsburgh; Carnegie Mellon, 2014-
- KHALED HARRAS, Senior Associate Dean for Faculty; Teaching Professor, Computer Science - Ph.D., University of California-Santa Barbara; Carnegie Mellon, 2007-
- ERIK HELIN, Special Lecturer, Spanish - M.A., Eastern Michigan University; Carnegie Mellon, 2006-
- AGUSTIN INDACO, Assistant Teaching Professor, Economics - Ph.D., City University of New York (CUNY); Carnegie Mellon, 2019-
- CHRISTOS KAPOUTSIS, Associate Teaching Professor, Computer Science - Ph.D., Massachusetts Institute of Technology; Carnegie Mellon, 2012-
- NIRAJ KHARE, Assistant Teaching Professor, Mathematics - Ph.D., The Ohio State University; Carnegie Mellon, 2014-
- DIVAKARAN LIGINLAL, Teaching Professor, Information Systems - Ph.D., University of Arizona-Tucson; Carnegie Mellon, 2009-
- J. PATRICK MCGINNIS, Distinguished Career Professor, Business Administration - M.A., Pittsburg State University; Carnegie Mellon, 1999-
- EZZOHRA MOUFID, Lecturer, Modern Languages - MS, University of Roehampton; Carnegie Mellon, 2019-
- THOMAS MITCHELL, Associate Teaching Professor, English - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2013-
- NIMER MURSHID, Assistant Teaching Professor of Chemistry, Carnegie Mellon, 2023-
- ADVITI NAIK, Assistant Teaching Professor, Carnegie Mellon, 2023-
- DEEPA NAIR, Assistant Teaching Professor, History - Ph.D., National University of Singapore; Carnegie Mellon, 2019-
- LAMA NASIF, Associate Teaching Professor of Arabic Studies, Carnegie Mellon, 2023-
- KEMAL OFLAZER, Teaching Professor, Computer Science - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2008-
- MARION OLIVER, Teaching Professor, Mathematics - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2004-
- TAEYONG PARK, Assistant Teaching Professor, Statistics - Ph.D., Washington University in St. Louis; Carnegie Mellon, 2017-
- SILVIA PESSOA, Co-Area Head, Art and Sciences; Teaching Professor, English - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2006-
- DANIEL PHELPS, Area Head, Information Systems; Associate Teaching Professor, Information Systems - Ph.D., Florida State University; Carnegie Mellon, 2007-
- BENJAMIN REILLY, Teaching Professor, History - Ph.D., University of Pittsburgh; Carnegie Mellon, 2004-
- GISELLE REIS, Area Head, Computer Science; Assistant Teaching Professor, Computer Science - Ph.D., Vienna University of Technology; Carnegie Mellon, 2016-
- DUDLEY REYNOLDS, Senior Associate Dean, Education; Teaching Professor, English - Ph.D., Indiana University-Bloomington; Carnegie Mellon, 2007-
- RYAN RILEY, Associate Area Head, Computer Science; Associate Teaching Professor, Computer Science - Ph.D., University of Purdue; Carnegie Mellon, 2017-
- VELI SAFAK, Assistant Teaching Professor, Economics - Ph.D., Georgetown University; Carnegie Mellon, 2019-
- REYA SALIBA, Instruction and Outreach Librarian; Carnegie Mellon, 2023-
- VARUN SHARMA, Assistant Teaching Professor, Marketing - Ph.D., Bocconi University; Carnegie Mellon, 2019-
- JEFFREY SQUIRES, Assistant Teaching Professor, English - Ph.D., University of Minnesota Twin-Cities; Carnegie Mellon, 2019-
- MICHAEL TRICK, Dean of Carnegie Mellon University in Qatar and Harry B. and James H. Higgins Professor of Operations Research - Ph.D., Georgia Institute of Technology; Carnegie Mellon, 2017-
- TATIANA USOVA, Director, Library - Master of Library and Information Studies, Simmons University; Carnegie Mellon, 2022-
- SAVANID VATANASAKDUL, Associate Teaching Professor, Information Systems - Ph.D., University of South Wales; Carnegie Mellon, 2017-
- ANNETTE SHOBA VINCENT, Teaching Professor, Biological Sciences - Ph.D., National University of Singapore; Carnegie Mellon, 2012-
- ANTHONY WESTON, Associate Teaching Professor, Mathematics; Carnegie Mellon, 2022-
- ZELEALEM YILMA, Associate Teaching Professor, Mathematics - Ph.D., Carnegie Mellon University; Carnegie Mellon, 2014-
- IHAB YOUNIS, Area Head, Biological Sciences; Associate Teaching Professor, Biological Sciences - Ph.D., Ohio State University; Carnegie Mellon, 2015-
- MOHAMED ZAYED, Associate Teaching Professor, Physics - D.Sc., ETH Zurich; Carnegie Mellon, 2017-

Interdisciplinary Programs

Carnegie Mellon University offers several degree programs and courses of study which are coordinated by multiple colleges, reflecting the interdisciplinary nature of the university. These are detailed below.

Intercollege Majors

- BXA Intercollege Degree Programs
 - Bachelor of Humanities and Arts Program
 - Bachelor of Engineering Studies and Arts Program
 - Bachelor of Science and Arts Program
 - Bachelor of Computer Science and Arts Program
- B.S. in Computational Finance
- B.S. in Music and Technology
- B.S. in Neuroscience
- B.S. in Psychology and Biological Sciences
- Major in General Studies

INTERCOLLEGE ADDITIONAL MAJOR

- Environmental & Sustainability Studies
- BXA Intercollege Degree Programs
 - Engineering and Arts

Intercollege Minors

- Minor in Computational Finance
- Minor in Environmental & Sustainability Studies
- Minor in Game Design (IDeATe)
- Minor in Health Care Policy and Management
- Minor in Immersive Technologies in Arts & Culture

BXA Intercollege Degree Programs

The BXA Intercollege Degree Programs enable students the freedom to individualize their educational experience by promoting integration, balance and innovation. BXA offers the following programs:

- Bachelor of Humanities and Arts
- Bachelor of Engineering Studies and Arts
- Bachelor of Computer Science and Arts
- Bachelor of Science and Arts
- Engineering and Arts Additional Major

For detailed information on the BXA Intercollege Degree Programs, go to BXA Intercollege Degree Programs (p. 893).

Bachelor of Science in Computational Finance

The Mellon College of Science, the Heinz College of Public Policy and Management and the Tepper School of Business jointly offer a degree uniquely designed to meet the quantitative needs of the finance industry. Modeled after the highly successful Carnegie Mellon Master of Science in Computational Finance, this degree allows students to develop a deep knowledge of mathematics, probability, statistics, and the applications of these disciplines to finance. Students who complete this degree may directly enter the finance industry, enter other industries where applied mathematics training is appropriate, or pursue advanced degrees in economics, finance or the mathematical sciences. Students entering the work force upon completion of this degree may wish to later complement their undergraduate degree with a Master's degree in Business Administration or another professional degree. Students who might eventually pursue doctoral degrees in economics, finance, statistics or mathematics should seek advising on how to use their electives in order to prepare for graduate work in their chosen disciplines.

The Bachelor of Science in Computational Finance is an Intercollege Program. Students may pursue Computational Finance as their primary major with either the Mellon College of Science (MCS) or the Tepper School of Business (Tepper) as their home college. The coursework required for the major is essentially the same in each case, with a few minor exceptions outlined below. The general education requirements for the degree depend on the student's home college.

Students who pursue Computational Finance as an additional major will remain in the college of their primary major. Additional majors must complete the Major Requirements outlined below, but not the General Education Requirements outlined for MCS and Tepper students. Additional majors will complete the general education requirements for their home college.

Admission to the major in Computational Finance is by application. Applications are accepted each fall and spring semester. The application deadline has traditionally been just after the mid-semester break.

Applicants must have taken (or be currently taking) at the time of application: 21-127 Concepts of Mathematics (or 21-128), 21-241 Matrices and Linear Transformations (or 21-242), 21-270 Introduction to Mathematical Finance. Students from any college or program at Carnegie Mellon are welcome to apply to enroll in the major. Additional information about computational finance and the Undergraduate Computational Finance Program at Carnegie Mellon can be found on the BSCF Program website.

Several majors are prohibited in combination with the Computational Finance major (either as Primary/Additional majors or as Dual Degrees) due to excessive overlap with the Computational Finance curriculum. These include the Business Administration major, the major in Mathematical Sciences (including any of the various concentrations), and the major in Economics and Mathematical Sciences.

Major Requirements

The major in Computational Finance is built around a core sequence of courses in mathematical finance. This core is supported by courses providing foundational mathematical skills and augmented with coursework in the related areas of Statistics, Computer Science, and Economics. Additionally the major provides training in the "soft skills" required for work in a corporate environment. The major also requires the completion of several depth electives, allowing students to tailor their education to their particular interests and needs.

The major requirements are the same for additional majors as they are for majors whose home college is MCS. There are a few slight differences for students whose home college is Tepper. These differences are described in the sections for Depth Electives and Professional Development below.

Foundations

| | | |
|--------|-------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-241 | Matrices and Linear Transformations | 11 |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-260 | Differential Equations | 9 |
| 21-369 | Numerical Methods | 12 |
| 70-122 | Introduction to Accounting | 9 |

Mathematical Finance

| | | |
|--------|---------------------------------------|---|
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-370 | Discrete Time Finance | 9 |
| 21-420 | Continuous-Time Finance | 9 |
| 46-977 | MSCF Studies in Financial Engineering | 6 |

Statistics

| | | |
|--------|---------------------------------------|---|
| 21-325 | Probability | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-401 | Modern Regression | 9 |

Programming

| | | |
|--------|--|----|
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |

Economics

| | | |
|-----------|--|---|
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |

| | | |
|--------|------------------------------|---|
| 73-103 | Principles of Macroeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |

Professional Development

| | | |
|--------|--|---|
| 94-700 | Organizational Design & Implementation | 6 |
| 95-717 | Writing for Information Systems Management | 6 |
| 95-718 | Professional Speaking | 6 |

Note: Majors in the Tepper School of Business take 70-311 Organizational Behavior as part of the Functional Business Core curriculum. This course will satisfy the 94-700 Organizational Design & Implementation requirement for these students. Majors in the Tepper School of Business also take 70-340 Business Communications as part of the Functional Business Core curriculum. This course will satisfy the 95-717 Writing for Information Systems Management requirement for these students.

Depth Electives

Depth electives give students an opportunity to tailor their coursework to their particular interests. Students completing the major will take three depth electives (the minimum requirement is 24 units - the equivalent of two 9 unit courses and one 6 unit course).

Note: Tepper students are required to select 70-391 Finance as one of their depth electives.

Depth electives are intended to develop a student's background in an area that is applicable to the finance industry. Courses in finance or programming generally qualify as depth electives. Mathematics, Statistics, or Economics courses in areas applicable to finance also qualify. Computational Finance majors may have the opportunity to take MSCF courses (as described below) and these may also be counted as depth electives.

There is no definitive list of approved depth electives. The courses listed below have been taken as depth electives in recent years, but other courses could be approved upon request

| | | |
|--------|--|----|
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 10-601 | Introduction to Machine Learning (Master's) | 12 |
| 10-605 | Machine Learning with Large Datasets | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-351 | Algorithms and Advanced Data Structures | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| 21-393 | Operations Research II | 9 |
| 21-355 | Principles of Real Analysis I | 9 |
| 21-378 | Mathematics of Fixed Income Markets | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |
| 36-410 | Introduction to Probability Modeling | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 36-463 | Special Topics: Multilevel and Hierarchical Models | 9 |
| 36-464 | Special Topics: Psychometrics: A Statistical Modeling Approach | 9 |
| 70-391 | Finance | 9 |
| 70-492 | Investment Analysis | 9 |
| 70-495 | Corporate Finance | 9 |
| 70-497 | Derivative Securities | 9 |

MSCF Courses

Computational Finance majors are required to take 46-977 MSCF Studies in Financial Engineering. They may also have the opportunity to take up to four more MSCF courses. Permission to enroll in these courses requires (1) approval from the BSCF program, (2) approval of the course instructor, and (3) space available in the course. The MSCF curriculum (<https://www.cmu.edu/mscf/academics/curriculum/>) with course descriptions is described on the MSCF website (<https://www.cmu.edu/mscf/>).

Some MSCF courses cover material in the undergraduate curriculum and thus are not generally suitable. Other courses require background that is difficult to obtain as an undergraduate. Students interested in taking MSCF courses are encouraged to discuss their interest with their BSCF advisor as early as possible.

General Education Requirements

Students completing Computational Finance as an additional major will complete the general education requirements from their home department and college. Students completing Computational Finance as their primary major in either MCS or Tepper will complete a modified version of the general education requirements from their home college. These requirements are outlined below.

General Education Requirements for MCS Students

Students in the Mellon College of Science completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

| | | |
|-----------|---|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
| 76-101 | Interpretation and Argument | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |
| or 76-106 | Writing about Literature, Art and Culture | |
| or 76-107 | Writing about Data | |
| or 76-108 | Writing about Public Problems | |

Technical Breadth Requirement

A student must take at least 18 units of MCS technical breadth courses total, one from "Life Sciences" and one from "Physical Sciences". AP/IB/Cambridge credit may not be used to fulfill these requirements. CMU placement exam credit can be used to fill these requirements. Transfer courses from an accredited college/university will be considered for these technical breadth requirements. To support educational exploration, courses taken to satisfy BSCF major requirements may not be used to satisfy the general education requirements. Courses that have been approved for each category can be found below.

A. Life Sciences

(Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

LIFE SCIENCES COURSES

| | | |
|--------|---|------|
| 02-250 | Introduction to Computational Biology | 12 |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | Var. |
| 03-116 | Phage Genomics Research * Offered only in Doha | 6 |
| 03-117 | Frontiers, Analysis, and Discovery in Biological Sciences | 6 |
| 03-121 | Modern Biology | 9 |
| 03-151 | Honors Modern Biology | 10 |
| 03-124 | Modern Biology Laboratory | 9 |
| 03-125 | Evolution | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 03-135 | Structure and Function of the Human Body | 9 |
| 03-161 | Molecules to Mind | 9 |
| 03-231 | Honors Biochemistry | 9 |
| 03-232 | Biochemistry I | 9 |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 42-202 | Physiology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |

B. Physical Sciences

(Some courses have prerequisites that can be satisfied by AP, IB, Cambridge A Level Exams. Please check the prerequisites requirements as necessary.)

PHYSICAL SCIENCES COURSES

| | | |
|--------|---|----|
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-107 | Honors Chemistry: Fundamentals, Concepts and Applications | 10 |
| 09-111 | Nanolegos: Chemical Building Blocks | 9 |
| 09-214 | Physical Chemistry | 9 |
| 09-217 | Organic Chemistry I | 9 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |

| | | |
|--------|---|----|
| 09-348 | Inorganic Chemistry | 10 |
| 33-121 | Physics I for Science Students | 12 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| 33-141 | Physics I for Engineering Students | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 33-151 | Matter and Interactions I | 12 |
| 33-152 | Matter and Interactions II | 12 |
| 33-211 | Physics III: Modern Essentials | 10 |
| 33-224 | Stars, Galaxies and the Universe | 9 |
| 33-225 | Quantum Physics and Structure of Matter | 9 |

Non-Technical Elective: Cognition, Choice, and Behavior

One of the following:

| | | |
|--------|---|---|
| 80-100 | Introduction to Philosophy | 9 |
| 80-130 | Introduction to Ethics | 9 |
| 80-150 | Nature of Reason | 9 |
| 80-180 | Nature of Language | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-330 | Ethical Theory | 9 |
| 85-102 | Introduction to Psychology | 9 |
| 85-211 | Cognitive Psychology | 9 |
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |
| 85-261 | Psychopathology | 9 |
| 88-120 | Reason, Passion and Cognition | 9 |

Though any of these courses will satisfy the Cognition, Choice, and Behavior requirement, students are strongly encouraged to consider taking one of the ethics courses: 80-130 or 80-330.

Non-Technical Elective: Cultural Analysis

One of the following:

| | | |
|--------|--|---|
| 57-173 | Survey of Western Music History | 9 |
| 57-209 | The Beatles | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 79-104 | Global Histories | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-225 | West African History in Film | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-239 | History of the American Working Class | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-281 | Introduction to Religion | 9 |
| 79-345 | Roots of Rock & Roll | 9 |
| 79-350 | Early Christianity | 9 |
| 80-100 | Introduction to Philosophy | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |

| | | |
|--------|-----------------------------------|---|
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 82-xxx | Any courses from Modern Languages | |

Non-Technical Electives: Two Additional Courses

In addition to the Cognition, Choice and Behavior and the Cultural Analysis requirements, majors in MCS must take two more courses (at least 18 units) from any of the departments in DC, CFA or Tepper, subject to the list of deletions (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html>) and additions (<https://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html>) maintained by MCS.

Additional Notes

BSCF majors in MCS may use AP credits to satisfy nontechnical general education requirements. However, students cannot count more than 18 units from AP/IB/Cambridge exam credit towards these requirements. Transfer courses from an accredited college/university will be considered for these nontechnical breadth requirements. To support educational exploration, courses taken to satisfy BSCF major requirements may not be used to satisfy the general education requirements.

General Education Requirements for Tepper Students

Students in the Tepper School of Business completing the Computational Finance major as their primary major must complete the requirements below in addition to the major requirements.

Tepper Functional Business Core

Computational Finance majors whose home college is Tepper will complete a modified version of the Tepper Functional Business Core curriculum.

The Functional Business Core of the Undergraduate Business Administration Program includes 70-122 Introduction to Accounting, which is required by all Computational Finance majors. It also includes 70-391 Finance, which Tepper students majoring in Computational Finance must select as one of their Depth Electives. In addition, Tepper students pursuing the B.S. in Computational Finance must complete six other courses from the Functional Business Core.

These courses are:

| | | |
|--------|------------------------------|----|
| 70-106 | Business Science | 9 |
| 70-311 | Organizational Behavior | 9 |
| 70-332 | Business, Society and Ethics | 9 |
| 70-371 | Operations Management | 9 |
| 70-381 | Marketing I | 9 |
| 70-401 | Management Game | 12 |

Liberal Arts & Sciences Breadth Requirements

Candidates for the B.S. in Computational Finance must complete the Liberal Arts & Sciences Breadth Requirements as described in the catalog entry for the B.S. Degree in Business Administration.

Sample Curricula**MCS Sample Curriculum**

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Mellon College of Science. This is an example of how an MCS student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127

Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

| Freshman | |
|---|---|
| Fall | Spring |
| 15-110 Principles of Computing | 15-112 Fundamentals of Programming and Computer Science |
| 21-120 Differential and Integral Calculus | 21-122 Integration and Approximation |
| 76-101 Interpretation and Argument | 70-122 Introduction to Accounting |
| 99-101 Computing @ Carnegie Mellon | xx-xxx Science Requirement |
| xx-xxx Science Requirement | xx-xxx Elective |

| Sophomore | |
|---|---|
| Fall | Spring |
| 21-241 Matrices and Linear Transformations | 21-270 Introduction to Mathematical Finance |
| 21-259 Calculus in Three Dimensions | 21-127 Concepts of Mathematics |
| 21-260 Differential Equations | 21-369 Numerical Methods |
| 73-102 Principles of Microeconomics | 73-103 Principles of Macroeconomics |
| xx-xxx Humanities, Social Sciences, or Fine Arts Elective | xx-xxx Elective |

| Junior | |
|---|---|
| Fall | Spring |
| 21-325 Probability | 21-420 Continuous-Time Finance |
| 21-370 Discrete Time Finance | 36-226 Introduction to Statistical Inference |
| 73-240 Intermediate Macroeconomics | xx-xxx Humanities, Social Sciences, or Fine Arts Elective |
| 15-122 Principles of Imperative Computation | xx-xxx Humanities, Social Sciences, or Fine Arts Elective |
| xx-xxx Elective | xx-xxx Depth Elective |

| Senior | |
|---|---|
| Fall | Spring |
| 46-977 MSCF Studies in Financial Engineering | 95-717 Writing for Information Systems Management |
| 94-700 Organizational Design & Implementation | 95-718 Professional Speaking |
| 36-401 Modern Regression | xx-xxx Depth Elective |
| xx-xxx Depth Elective | xx-xxx Humanities, Social Sciences, or Fine Arts Elective |
| xx-xxx Elective | xx-xxx Elective |
| xx-xxx Elective | xx-xxx Elective |

Tepper Sample Curriculum

What follows is the detailed curriculum for the degree Bachelor of Science in Computational Finance in the Tepper School of Business. This is an example of how a Tepper student might meet the requirements of the Computational Finance major. It is not expected that every student will follow this sequence. In particular, well prepared students should consider taking 21-270 Introduction to Mathematical Finance during their Freshman Spring semester. Students intending to do so are encouraged to take 21-127

Concepts of Mathematics or 21-241 Matrices and Linear Transformations during their Freshman Fall semester.

| Freshman | |
|---|---|
| Fall | Spring |
| 15-110 Principles of Computing | 15-112 Fundamentals of Programming and Computer Science |
| 21-120 Differential and Integral Calculus | 21-122 Integration and Approximation |
| 73-102 Principles of Microeconomics | 21-241 Matrices and Linear Transformations |
| 70-106 Business Science | 73-103 Principles of Macroeconomics |
| 76-101 Interpretation and Argument | xx-xxx Breadth Course |
| 99-101 Computing @ Carnegie Mellon | xx-xxx Breadth Course |

| Sophomore | |
|-------------------------------------|---|
| Fall | Spring |
| 21-127 Concepts of Mathematics | 21-270 Introduction to Mathematical Finance |
| 21-259 Calculus in Three Dimensions | 21-325 Probability |
| 21-260 Differential Equations | 70-311 Organizational Behavior |
| 70-122 Introduction to Accounting | 70-381 Marketing I |
| xx-xxx Elective | 73-240 Intermediate Macroeconomics |

| Junior | |
|---|--|
| Fall | Spring |
| 21-369 Numerical Methods | 21-420 Continuous-Time Finance |
| 21-370 Discrete Time Finance | 36-226 Introduction to Statistical Inference |
| 70-391 Finance | 70-371 Operations Management |
| 15-122 Principles of Imperative Computation | xx-xxx Breadth Course |
| xx-xxx Breadth Course | xx-xxx Breadth Course |

| Senior | |
|--|---|
| Fall | Spring |
| 36-401 Modern Regression | 95-717 Writing for Information Systems Management |
| 46-977 MSCF Studies in Financial Engineering | 95-718 Professional Speaking |
| 70-332 Business, Society and Ethics | xx-xxx Depth Elective |
| 70-401 Management Game | xx-xxx Breadth Course |
| xx-xxx Depth Elective | xx-xxx Breadth Course |
| | xx-xxx Elective |

Minor in Computational Finance

Unlike the major in Computational Finance, there is no application process for the minor in Computational Finance, however in order to declare the minor in Computational Finance, a student must satisfy one of the following sets of requirements:

1. Completion of 21-270 Introduction to Mathematical Finance with a grade of A and an overall QPA of at least 3.20; OR
2. Completion of 21-270 Introduction to Mathematical Finance and 21-370 Discrete Time Finance with an average grade of B and an overall QPA of at least 3.00; OR
3. Completion of 21-270 Introduction to Mathematical Finance and 21-378 Mathematics of Fixed Income Markets with an average grade of B and an overall QPA of at least 3.00.

When a student has met the necessary requirements, he or she may declare the minor by contacting the Associate Director of the Undergraduate Computational Finance program.

Note: For students who have a grade of P in either 21-270 or 21-378 from the Spring 2020 semester (and only that semester) these requirements have been altered slightly. The grade of P will not be counted toward the averages in conditions 2 or 3. This effectively makes the requirements

1. Completion of 21-270 Introduction to Mathematical Finance with a grade of A and an overall QPA of at least 3.20; OR

2. Completion of 21-270 Introduction to Mathematical Finance and 21-370 Discrete Time Finance with an average grade of B and an overall QPA of at least 3.00; OR

2a. Completion of 21-270 Introduction to Mathematical Finance with a grade of P in Spring 2020, and completion of 21-370 Discrete Time Finance with a minimum grade of B and an overall QPA of at least 3.00; OR

3. Completion of 21-270 Introduction to Mathematical Finance and 21-378 Mathematics of Fixed Income Markets with an average grade of B and an overall QPA of at least 3.00; OR

3a. Completion of 21-270 Introduction to Mathematical Finance with a grade of P in Spring 2020, and completion of 21-378 Mathematics of Fixed Income Markets with a minimum grade of B and an overall QPA of at least 3.00.

| | | |
|-----------|---|------|
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 9-11 |
| or 21-256 | Multivariate Analysis | |
| or 21-268 | Multidimensional Calculus | |
| or 21-269 | Vector Analysis | |
| 21-260 | Differential Equations | 9-10 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| 21-270 | Introduction to Mathematical Finance | 9 |
| 21-370 | Discrete Time Finance * | 9 |
| 21-420 | Continuous-Time Finance ** | 9 |

To avoid excessive double counting, Computational Finance minors may not count 21-270 Introduction to Mathematical Finance, 21-370 Discrete Time Finance or 21-420 Continuous-Time Finance toward any other requirement.

* The prerequisites for 21-370 are 21-270 and either 21-256 or 21-259, and the co-requisite is 70-207, 21-325, 36-225 or 36-217. Note that 70-207 is not accepted as a prerequisite for 21-420.

** The prerequisites for 21-420 are 21-260, 21-370 and one of the following three calculus based probability courses: 21-325, 36-225 or 36-217. Note that 70-207 is not a sufficient preparation in probability. Also note that 21-122 is a prerequisite for 21-260 and that 21-127 is recommended for 21-241.

Students minoring in Computational Finance are strongly encouraged to take one or two economics course, e.g., 73-102, 73-103, 73-230, or 73-240.

Environmental & Sustainability Studies

Program in Environmental and Sustainability Studies

Abigail Owen, Program Director & Program Faculty, Minor and Additional Major in Environmental & Sustainability Studies
 Ryan Sullivan, Program Faculty, Minor and Additional Major in Environmental & Sustainability Studies
 Neil Donahue, Director, Steinbrenner Institute for Environmental Education and Research
 Joe Moore, Co-Advisor, Minor and Additional Major in Environmental & Sustainability Studies
 Kathy Zhang, Program Assistant

<https://www.cmu.edu/steinbrenner/undergraduate-program/index.html>
[\(https://www.cmu.edu/steinbrenner/undergraduate-program/\)](https://www.cmu.edu/steinbrenner/undergraduate-program/)

Maggie Braun, Associate Dean for Undergraduate Affairs, Mellon College of Science

Sharon Carver, Associate Dean for Educational Affairs, Marianna Brown Dietrich College of Humanities & Social Sciences

The Steinbrenner Institute for Environmental Education & Research, the Dietrich College of Humanities & Social Sciences, and the Mellon College of Science have joined together to establish the interdisciplinary Program in Environmental & Sustainability Studies, offering a Minor or an Additional Major.

The Minor and Additional Major in Environmental & Sustainability Studies are designed to be accessible for any undergraduate student at Carnegie Mellon University, regardless of primary major and college, and without extensive prerequisite barriers. Building from core coursework, students can tailor their elective coursework, with intensive guidance from program advisors, to integrate appropriate electives from a wide range of possible courses to develop a coherent course of study with appropriate depth and breadth.

Additional Major in Environmental and Sustainability Studies

The additional major is designed to allow students from any college at CMU to build on the depth of their primary major and address the breadth of intrinsically interdisciplinary issues associated with the environment and sustainability.

There is no application process for the program in Environmental and Sustainability Studies, however a student must declare the Minor or Additional Major by contacting the Advisor or Program Director of the Environmental and Sustainability Studies program. Due to limited enrollment for a small class size in core course 66-236 "Introduction to Environmental Ideas" (9 Units), students are encouraged to declare the Minor or Additional Major as early as possible, so they can receive priority in course registration.

The Additional Major combines natural science, social science, and humanistic studies. These are co-equal. How Earth functions as a system is fundamental: key topics include climate, ecosystems, environmental chemistry (the behavior of molecules within the environment) and energy systems. Human interactions with the environment, and so the details of how cultural, political, and social systems function, are critical to understand, with an emphasis on sustainability and the environment. Issues of ethics, equity, and justice, situated in historical context, are vital to a full and complex understanding with a goal of equitable and appropriate solutions to environmental crises.

The three pillars are:

1. Earth and Environmental Science. Majors should understand how the Earth works as a system, with more advanced understanding of selected scientific topics associated with Environment and Sustainability.
2. Political Economy. Majors should understand the consequences and options of economics and policy at the local, regional, and global level.
3. Humanities for Environment and Sustainability. Additional Majors should understand cultural, social, historical, ethical, and political aspects of environment and sustainability, including environmental, climate, and social justice.

Students who pursue the Additional Major will be able to:

- Apply humanistic, social, and scientific perspectives for problems of environment and sustainability
- Distinguish among scientific methods for evaluating problems of environment and sustainability
- Explain how aspects of history, culture, ethics, language, and arts relate to environment and sustainability, including goals for environmental justice and global climate justice.
- Assess sources of data about environment and sustainability
- Formulate a research question for interdisciplinary studies of environment and sustainability. Identify discipline-specific methods for exploring or answering the questions posed and use the chosen methods to gather and analyze evidence

Double-Counting

Maximum 3 courses, regardless of Units, can be double-counted for the Additional Major from any other Minor, Major, or Master's program. This maximum does not apply to General Education courses.

General Education courses

Courses taken to fulfill a General Education requirement for the student's college (the college of the student's primary major) are not calculated as "double-counting" for the Additional Major in Environmental and Sustainability Studies.

AP credit

AP courses are not counted towards requirements for the Additional Major in Environmental and Sustainability Studies.

Study abroad

Courses taken abroad may count towards Electives for the Additional Major, if accepted for transfer credit by the relevant CMU department and approved by the Program Director.

Requirements for the Additional Major in Environmental & Sustainability Studies

- Minimum 102 Units Total for students with primary majors in CFA, Dietrich, Tepper
- Minimum 105 Units Total for students with primary majors in MCS, Engineering, SCS

Core Courses: Complete 27 Units for students with Primary majors in CFA, Dietrich, Tepper; Complete 30 Units for Students with Primary Majors in MCS, Engineering, SCS

| Course Number | Course Title | Units |
|---------------|---|-------|
| 24-291 | Environmental Systems on a Changing Planet Cross-listed as 09-291 | 9 |
| 24-381 | Environmental Systems on a Changing Planet: Science & Engineering Addendum Cross-listed as 09-381. This 3-unit addendum course is required for students with primary majors in MCS, Engineering, or SCS. | 3 |
| 66-236 | Introduction to Environmental Ideas | 9 |
| 66-506 | Senior Capstone | 9 |

Earth and Environmental Science - Complete any one (minimum 9 Units)

| Course Number | Course Title | Units |
|---------------|---|-------|
| 03-128 | Biology for Life Special Topics Section 5, "Tropical Ecology" (9 units) offered at CMU Study Abroad Program in Costa Rica; Without prerequisite | 9 |
| 03-140 | Ecology and Environmental Science Without prerequisite | 9 |
| 33-115 | Physics for Future Presidents Without prerequisite | 9 |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 09-510 | Chemistry and Sustainability | 9 |
| 09-524 | Environmental Chemistry | 9 |
| 09-529 | Introduction to Sustainable Energy Science | 9 |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| 33-226 | Physics of Energy | 9 |

Global Course - Complete any one (3 Units)

| Course Number | Course Title | Units |
|---------------|--|-------|
| 99-384 | Technology, Humanity, and Social Justice: Health Each semester, a new 3-Unit course 99-xxx is offered on Global themes, in partnership with University of Pittsburgh's Global Studies Center. | 3 |

Statistics & Data Science - Complete 9 Units

| Course Number | Course Title | Units |
|---------------|--|-------|
| 36-200 | Reasoning with Data This requirement can only be fulfilled with a course taken in the Department of Statistics & Data Science at CMU. AP Statistics does not fulfill this requirement. Students with AP credit can place into a higher-level course offered by the same Department, for example 36-202 or 36-290. | 9 |

Political Economy - Complete any one (Minimum 9 Units)

| Course Number | Course Title | Units |
|---------------|---|-------|
| 19-101 | Introduction to Engineering and Public Policy Without prerequisite | 12 |
| 79-300 | History of American Public Policy Without prerequisite | 9 |
| 84-110 | Foundations of Political Economy Without prerequisite | 9 |
| 84-226 | International Relations Without prerequisite | 9 |
| 84-325 | Contemporary American Foreign Policy Without prerequisite | 9 |
| 88-344 | Systems Analysis: Environmental Policy Without prerequisite | 9 |

| | | |
|--------|---|---|
| 73-332 | Political Economy | 9 |
| 73-408 | Law and Economics | 9 |
| 73-427 | Sustainability, Energy, and Environmental Economics | 9 |
| 84-310 | International Political Economy | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |

Electives for Environmental & Sustainability Studies - Complete 45 Units

For the Additional Major, select and complete at least 45 Units of eligible electives in consultation with the Program Advisor and/or Program Director. At least 36 out of 45 Units of Electives for the Additional Major should be "External electives" completed outside of the college where the student's primary major is housed; this is to encourage students to pursue interdisciplinary breadth. The remaining 9 Units of Electives for the Additional Major are "Free electives" from any college, including the student's own primary college.

Example

A student with a primary Major in Art (College of Fine Arts) could complete up to 9 Units of Electives for the Additional Major within the College of Fine Arts. This means up to 9 Units of Electives could be taken in Music, Design, Architecture, Drama, or Art; the remaining 36 Units of Electives must come from outside CFA: from Dietrich, Engineering, Business, or Science.

Electives are vetted by the program director from the CMU course catalog and listed each term based on the following criteria. Additional courses meeting these criteria can be approved by the program director.

Additional courses from these categories always count as electives:

- Any additional courses listed in the above category "Earth and Environmental Science" can be counted as electives.
- Any additional courses listed in the above category "Political Economy" can be counted as electives.
- Any additional courses listed in the above category "Global Course" can be counted as electives.

Any further electives should:

- Broaden the reach of the student's interdisciplinary explorations in environment and sustainability
- Thematically, courses should either add to depth from above-listed categories: "Earth and Environmental Science"; "Environmental Humanities"; "Three Unit Global Course"; and/or "Political Economy";
- Or, electives should increase the student's interdisciplinary grasp of topics related to environment and sustainability, with particular emphasis on topics related to environmental justice and/or global climate justice.

Minor in Environmental and Sustainability Studies

There is no application process for the program in Environmental and Sustainability Studies, however a student must declare the Minor or Additional Major by contacting the Advisor or Program Director of the Environmental and Sustainability Studies program. Due to limited enrollment for a small class size in core course 66-236 "Introduction to Environmental Ideas" (9 Units), students are encouraged to declare the Minor or Additional Major as early as possible, so they can receive priority in course registration.

Students who pursue the minor will be able to:

- Identify humanistic, social, and scientific perspectives for problems of environment and sustainability
- Distinguish among scientific methods for evaluating problems of environment and sustainability
- Connect how aspects of history, culture, ethics, language, and arts relate to environment and sustainability, including goals for environmental justice and global climate justice
- Discuss sources of data about environment and sustainability

Double-Counting

Maximum 2 courses, regardless of Units, can be double-counted for the Minor from any other Minor, Major, or Master's program. This maximum does not apply to General Education courses.

General Education courses

Courses taken to fulfill a General Education requirement for the student's college (the college of the student's primary major) are not calculated as "double-counting" for the Minor in Environmental and Sustainability Studies.

AP credit

AP courses are not counted towards requirements for the Minor in Environmental and Sustainability Studies.

Study abroad

Courses taken abroad may count towards Electives for the Minor, if accepted for transfer credit by the relevant CMU department and approved by the Program Director.

Requirements for the Minor in Environmental & Sustainability Studies

- Minimum 66 Units Total for students with primary majors in CFA, Dietrich, Tepper

- Minimum 69 Units Total for students with primary majors in MCS, Engineering, SCS

Core Courses: Complete 18 Units for students with Primary majors in CFA, Dietrich, Tepper; Complete 21 Units for Students with Primary Majors in MCS, Engineering, SCS

| | Units |
|---|-------|
| 24-291 Environmental Systems on a Changing Planet Cross-listed as 09-291 | 9 |
| 24-381 Environmental Systems on a Changing Planet: Science & Engineering Addendum Cross-listed as 09-381. This 3-unit addendum course is required for students with primary majors in MCS, Engineering, or SCS. | 3 |
| 66-236 Introduction to Environmental Ideas | 9 |
| Global Course - Complete any one (3 Units) | Units |
| 99-384 Technology, Humanity, and Social Justice: Health | 3 |
| Statistics & Data Science - Complete 9 Units | Units |
| 36-200 Reasoning with Data This requirement can only be fulfilled with a course taken in the Department of Statistics & Data Science at CMU. AP Statistics does not fulfill this requirement. Students with AP credit can place into a higher-level course offered by the same Department, for example 36-202 or 36-290. | 9 |

Electives for Environmental & Sustainability Studies - Complete 36 Units

For the Minor, select and complete at least 36 Units of eligible electives in consultation with the Program Advisor and/or Program Director. At least 27 out of 36 Units of Electives for the Minor should be "External electives" completed outside of the college where the student's primary major is housed; this is to encourage students to pursue interdisciplinary breadth. The remaining 9 Units of Electives for the Minor are "Free electives" from any college, including the student's own primary college.

Example

A student with a primary Major in Art (College of Fine Arts) could complete up to 9 Units of Electives for the Minor within the College of Fine Arts. This means up to 9 Units of Electives could be taken in Music, Design, Architecture, Drama, or Art; the remaining 27 Units of Electives for the Minor must come from outside CFA: from Dietrich, Engineering, Business, or Science.

Electives are vetted by the program director from the CMU course catalog and listed each term based on the following criteria. Additional courses meeting these criteria can be approved by the program director.

Additional courses from these categories always count as electives:

- Any additional courses listed in the above category "Earth and Environmental Science" (see Additional Major requirements) can be counted as electives.
- Any additional courses listed in the above category "Political Economy" (see Additional Major requirements) can be counted as electives.
- Any additional courses listed in the above category "Global Course" can be counted as electives.

Any further electives should:

- Broaden the reach of the student's interdisciplinary explorations in environment and sustainability
- Thematically, courses should either add to depth from above-listed categories: "Earth and Environmental Science"; "Environmental Humanities"; "Three Unit Global Course"; and/or "Political Economy";
- Or, electives should increase the student's interdisciplinary grasp of topics related to environment and sustainability, with particular emphasis on topics related to environmental justice and/or global climate justice.

Game Design Minor - IDEATe

The *Game Design* minor is offered by the Entertainment Technology Center (<http://coursecatalog.web.cmu.edu/intercollegeprograms/etc.cmu.edu>) as part of the Integrative Design, Arts and Technology (<http://coursecatalog.web.cmu.edu/intercollegeprograms/ideate.cmu.edu>) (IDEATe) network. IDEATe offers students the opportunity to become immersed in a collaborative community of faculty and peers who share expertise, experience, and passions at the intersection of arts and technology. Students will engage in active "learning by doing" in shared labs and maker spaces. The program addresses current and emerging real-world challenges that require disciplinary expertise coupled with multidisciplinary perspectives and collaborative integrative approaches.

The IDEATe undergraduate curriculum consists of ten areas, all of which can also be taken as minors. The themes of these areas integrate knowledge in technology and arts: Game Design, Animation & Special Effects, Media Design, Design for Learning, Sonic Arts, Innovation and Entrepreneurship, Intelligent Environments, Physical Computing, Soft Technologies, and Immersive Technologies in Arts & Culture. For more information about the IDEATe network, please visit Undergraduate Options (p. 21).

Game design is an art, a craft, and a science. Students in the IDEATe *Game Design* minor will gain mastery in all three aspects through game design, development, and assessment. You will learn about the rich histories, theory, and practice of game creation taught by faculty experts, and have opportunities to collaborate across the many disciplines needed to make successful game experiences. Through coursework you will be able to realize your own unique aesthetics and voice by reflecting on your own game play and by thoughtfully critiquing the games of others. Through the minor students will be able to build a strong game design portfolio, deepen cultural sensitivities as a game designers, and expand their creative practice. In particular, you will gain skills and competencies in the following areas of game design:

- Game systems and mechanics design
- Interactive narrative and character development
- Visual and audio asset creation
- Game programming
- Interface design and user testing
- Collaboration and the iterative design process

Curriculum

One Computing Course - Minimum of 9 Units

| | Units |
|---|-------|
| 15-104 Introduction to Computing for Creative Practice | 10 |
| 15-110 Principles of Computing | 10 |
| 15-112 Fundamentals of Programming and Computer Science | 12 |
| 60-212 Intermediate Studio: Creative Coding | 12 |

One IDEATe Portal Course - Minimum of 9 Units

| | Units |
|---|-------|
| 16-223 IDEATe Portal: Creative Kinetic Systems | 10 |
| 18-090 Twisted Signals: Multimedia Processing for the Arts | 10 |
| 53-322 IDEATe: Little Games/Big Stories: Indie Roleplaying Game Studio Recommended Portal Course for this area | 9 |
| 60-125 IDEATe: Introduction to 3D Animation Pipeline | 12 |
| 60-218 IDEATe Portal: Real-Time Animation | 10 |
| 60-223 IDEATe Portal: Introduction to Physical Computing | 10 |
| 62-150 IDEATe Portal: Introduction to Media Synthesis and Analysis Recommended Portal Course for this area | 10 |

| | | |
|--------|--|---|
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
| 99-361 | IDeATe Portal | 9 |

IDeATe Game Design Courses - Minimum of 27 Units

| | | Units |
|---------------|--|-------|
| 05-418 | Design Educational Games | 12 |
| 05-499 | Special Topics in HCI For sections related to Game Design | 12 |
| 15-466 | Computer Game Programming | 12 |
| 53-230 | Programming for Game Designers | 12 |
| 53-320 | IDeATe Special Topics in Animation: Character Modeling | 6 |
| 53-321 | IDeATe Special Topics in Animation: Bipedal Rigging for Animation Production | 6 |
| 53-322 | IDeATe: Little Games/Big Stories: Indie Roleplaying Game Studio | 9 |
| 53-323 | IDeATE Storytelling Through Effects Animation | 6 |
| 53-353 | Understanding Game Engines | 9 |
| 53-371/76-368 | Role Playing Games Writing Workshop | 12 |
| 53-373 | Dynamic Motion and Game Experience | 12 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 53-471 | Game Design, Prototyping and Production | 15 |
| 53-472 | Advanced Game Studio | 12 |
| 53-558 | Reality Computing Studio | 12 |
| 60-333 | IDeATe: Animation Rigging | 10 |
| 60-419 | Advanced ETB: Experimental Game Studio: Digital Playgrounds | 10 |

Additional courses as available. Please refer to the IDeATe website for the list of Game Design courses for the current and upcoming semesters.

Double-Counting

Students may double-count up to two of their *Game Design* minor courses toward requirements for other majors or minors.

Major in General Studies

The Bachelor of Arts and Bachelor of Science in General Studies provide students a pathway through a broad educational foundation while adhering to the strong standards of a CMU degree.

The General Studies major covers both intercollegiate breadth and discipline-specific knowledge. The intercollegiate educational requirements expose students to a variety of intellectual and cultural approaches and provide serviceable knowledge on a range of topics. In addition to this liberal arts style foundation, students are required to declare and complete an academic minor. This concentrated study equips students with in-depth knowledge of a given professional field. Students are challenged to move beyond base assumptions and to demonstrate higher order creativity, analysis, and application. Additionally, the academic minor sends a concrete signal to future employers to indicate areas of interest and experience: "BA/BS in General Studies" also requires a "Minor in X". Near the end of their degree, General Studies students synthesize their educational pursuits. They are required to register for a 3+ unit Independent Study/Capstone to create a culminating project/paper. This course requires a supervising faculty advisor and is presented at Meeting of the Minds or an equivalent pre-approved public forum.

Eligibility and approval

A student cannot independently pursue this degree. Any student expressing interest in transferring to the General Studies major must discuss their motivation and alternative options with their academic advisor, receive approval from their college's Assistant/Associate Dean, and then be approved by the General Studies Academic Advisory Committee. Students must work with their Assistant/Associate Dean to first exhaust the following options:

- maintaining their current degree path,
- changing majors in one's home college, or
- transferring to another college at CMU.

In order to be considered for the General Studies major program, a student must fulfill all of the criteria:

1. A student must have successfully completed at least 180 units, 75% of which were completed at CMU.
2. A student must have passed the University's general education requirements: "First-Year Writing" and "Computing at CMU." See table below for full listing of courses that can satisfy these requirements.
3. A student must demonstrate the ability to be successful in their intended minor. Students must be on track to complete at least 50% of the minor's coursework at the point of application.
4. A student must create both a Success Plan and Curricular Plan with their advisor. This plan must include monthly meetings with their academic advisor, outline a plan for continual satisfactory academic progress, and be approved by their Assistant/Associate Dean.

If all the above criteria are met, each student's case is brought to the General Studies Academic Advisory Committee and must receive a majority vote to advance.

Degree Structure and Graduation Requirements

In accordance with Carnegie Mellon's standards and degree norms, all candidates must complete the following requirements in order to graduate with a General Studies major:

1. Apply and be approved by the General Studies Academic Advisory Committee as a General Studies Major.
2. Adhere to and make progress toward the agreed upon Success and Curricular plans.
3. Declare and complete an academic minor in your home college or gain approval and complete a minor in another college. (Transfer credit acceptance will be determined by the equivalent CMU department). Additional minors beyond the General Studies degree with a minor in x will not be considered unless the secondary minor's units are in addition to all of the General Studies degree requirements.
4. Graduation requirements are broadly defined as follows, and outlined in the following "Curriculum" section:
 - a. Earn a minimum of 360 units.
 - b. Students may count up to 40 non-factorable units with a maximum of 9 total non-factorable units of StuCo, ROTC, and P/E.
 - c. Students must have a minimum of 45 units in upper level courses, as defined by the course's home department (generally 300 level or above).
 - d. Pass/fail courses may not be used for the primary major or minor requirements (for courses that are otherwise letter graded). Pass/fail courses may not be used for the general education requirements of the degree.
 - e. Earn a QPA of at least 2.0 for all courses taken (For undergraduate students who enrolled at Carnegie Mellon as freshmen and whose freshman grades cause the cumulative QPA to fall below 2.00, this requirement is modified to be a cumulative QPA of at least 2.00 for all courses taken after the freshman year.)

Curriculum

Minimum units required for B.A./B.S. in General Studies 360

Seminar requirement

| | | |
|--------|------------------------------------|-----------------------|
| 99-430 | General Studies Capstone Course | 3-12, variable |
|--------|------------------------------------|-----------------------|

First-year writing REQUIREMENT

Complete a total of 9 units from the following courses.

| | | |
|--------|---|-----|
| 76-101 | Interpretation and Argument | 9 |
| 76-102 | Advanced First Year Writing: Special Topics | 9 |
| 76-106 | Writing about Literature, Art and Culture | 4.5 |
| 76-107 | Writing about Data | 4.5 |
| 76-108 | Writing about Public Problems | 4.5 |

general studies REQUIREMENTS

| | | |
|--------------------|---|-----------------|
| 99-101 | Computing @ CMU | 3 |
| Breadth coursework | Minimum of 18 units in each of three different CMU school/colleges covering at least five departments (this can include the school/department that the student is currently enrolled in). | 54 units |

The courses used to satisfy the breadth requirement must be in addition to the minimum total of 45 units in upper level courses required for the major.

MIDDLE STATES REQUIREMENTS

General Studies students should have a well-rounded education that fulfills Middle States Accreditation requirements, demonstrating learning in each of seven categories. Students will work with their advisor and associate dean (or equivalent) to guarantee that each category is fulfilled, recognizing what they have done while exploring other degrees across departments and colleges. Courses counting for their major and/or minor can be used to fulfill these requirements.

| | |
|---|-----------------------|
| Communication (oral, written, and visual) | Variable units |
| Information literacy | Variable units |
| Critical thinking | Variable units |
| Cultural and social understanding | Variable units |
| Personal development | Variable units |
| Quantitative reasoning | Variable units |
| Scientific reasoning | Variable units |

Minor in Immersive Technologies in Arts & Culture

Students in the Immersive Technologies in Arts & Culture (<https://ideate.cmu.edu/undergraduate-programs/immersive-technologies-in-arts-culture/>) minor will be hybrid technologists, media-makers, and storytellers who can create mediated experiences at the intersection of technology, design, and the humanities. They will be equipped with the social consciousness, global awareness, and cross-cultural skills needed to forge positive new paths for immersive media going into the future.

Students in the minor will learn to construct and deconstruct immersive and augmented experiences with respect to the cultural, socio-emotional, and embodied aspects of human experience. They will develop the technical know-how and creative production skills to collaboratively author original narratives and prototype spatially mediated experiences. In the making of augmented and immersive media, students will explore the narrative possibilities and technical affordances of the genre while attending to the aesthetic considerations, humanistic concerns, and design conventions defining this emerging mode of cultural production.

One IDEATE Portal Course (minimum of 9 units):

| | | |
|--------|--|---|
| 82-250 | Digital Realities: Introducing Immersive Technologies for Arts and Culture | 9 |
|--------|--|---|

One Intercultural Focus Course (minimum of 9 units):

| | | |
|--------|--|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |

One Computing Course (minimum of 9 units):

| | | |
|--------|--|----|
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 60-212 | Intermediate Studio: Creative Coding | 12 |

IDEATE Immersive Technologies Courses (minimum of 27 units)*:

| | | |
|-----------|--|----|
| 15-365 | Experimental Animation | 12 |
| or 60-422 | Advanced ETB: Experimental Animation | |
| 15-463 | Computational Photography | 12 |
| 53-353 | Understanding Game Engines | 9 |
| 53-373 | Dynamic Motion and Game Experience | 12 |
| 53-376 | 360 Story and Sound | 12 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 53-558 | Reality Computing Studio | 12 |
| 54-397 | Sound Design For Interactive Environments | 9 |
| 54-399 | Decoding Media | 9 |
| 60-413 | Advanced ETB: Real-Time Animation | 10 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |

*Additional courses are available. Please check IDEATE Courses (<https://ideate.cmu.edu/courses/current-courses.html>) for the options for the current and upcoming semester.

Double-counting: Students may double-count up to two of their IDEATE minor courses for other requirements.

Minor in Health Care Policy and Management**Sponsored by:**

Heinz College of Information Systems and Public Policy
Dietrich College of Humanities and Social Sciences
Mellon College of Science

Faculty Advisors:

Jason D'Antonio, Mellon College of Science
James F. Jordan, H. John Heinz III College

The face of health care is changing. The practice of medicine is being fundamentally altered by the forces of change in public policy, health care organizations and in the industry as a whole. The role of individual professionals in this industry is changing as rapidly as the industry itself. Traditional career paths have disappeared overnight to be replaced by new opportunities that require new skills. New organizations are placing new demands on their professional and medical staffs. The criteria of efficiency and financial stability are entering the domains of diagnosis and treatment.

This minor is designed to provide students considering a career in the health professions with an understanding of how these changes are likely to affect their careers. Students will become familiar with the critical policy and management issues and will begin to learn to operate effectively in the emerging health care environment. The curriculum combines economic, organizational, managerial, historical and psychological perspectives on these issues to provide a foundation for a deepened understanding of the changing structure of health care organizations and policy.

Required Courses for HCPM Minor

A total of 54 units are required to complete this minor. Entry into the minor requires completion of 73-102 Principles of Microeconomics or the equivalent by approval.

Required Courses

Complete a total of 21 units from the following:

| | | |
|--------|--|---|
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 90-436 | Health Systems | 6 |
| 90-472 | Health Policy | 6 |

Elective Courses

Complete a minimum of 24 units from these two sections:

| | | |
|-----------------------|--------------------------------|----|
| Heinz College Courses | | |
| 94-409 | Healthcare Information Systems | 12 |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |

| | | |
|---------------------------|--|----|
| 90-834 | Health Care Geographical Information Systems | 12 |
| Other courses as approved | | |

Humanities and Social Sciences Courses (9 units each)

| | | |
|---------------------------|--|---|
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 42-444 | Medical Devices | 9 |
| Other courses as approved | | |

Please note that some of these courses have prerequisites that will not count toward the completion of the requirements for this minor.

Elective Focus Areas

Focus areas are suggested groupings of electives based on student interest. Students *do not* need to take all electives within one focus area; they are free to choose their 18-unit elective minimum from any combination of focus areas.

| | | |
|--|---------------------------|-------|
| Health Management/Administration Focus | | Units |
| 90-832 | Health Law | 6 |
| 80-245 | Medical Ethics | 9 |
| 76-494 | Healthcare Communications | 9 |

| | | |
|---------------------------|--|-------|
| Health Policy Focus | | Units |
| 73-328 | Health Economics | 12 |
| 90-832 | Health Law | 6 |
| 90-433 | Population Health | 6 |
| 88-365/90-882 | Behavioral Economics and Public Policy | 9 |
| Other courses as approved | | |

| | | |
|-----------------------------|--|-------|
| Health Analytics & IT Focus | | Units |
| 94-409 | Healthcare Information Systems | 12 |
| 90-834 | Health Care Geographical Information Systems | 12 |
| 42-444 | Medical Devices | 9 |
| Other courses as approved | | |

B.S. in Psychology & Biological Sciences

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

This major is intended to reflect the interdisciplinary nature of current research in the fields of biology and psychology, as well as the national trend in some professions to seek individuals broadly trained in both the social and natural sciences.

Note: Students entering from the Dietrich College of Humanities and Social Sciences will earn a Bachelor of Science in Psychology and Biological Sciences. Students in the Mellon College of Science will earn a Bachelor of Science in Biological Sciences and Psychology.

Depending on a student's home college (DC or MCS), General Education (GenEd) requirements will be different. GenEd requirements for DC (p. 321) and MCS (p. 582) are found on their respective Catalog pages.

Degree Requirements:

| | | |
|--|--|-----------|
| Biological Sciences | | Units |
| 03-151 | Honors Modern Biology | 10 |
| or 03-121 Modern Biology | | |
| 03-220 | Genetics | 9 |
| or 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | | |
| 03-231 | Honors Biochemistry | 9 |
| 03-320 | Cell Biology | 9 |
| 03-343 | Experimental Techniques in Molecular Biology | 12 |
| 03-411 | Topics in Research | 1 |
| 03-412 | Topics in Research | 1 |
| 03-xxx | General Biology Elective ¹ | 9 |
| 03-3xx | Advanced Biology Elective ¹ | 18 |
| Total Biology units | | 78 |

¹ Please see description and requirements for electives under the B.S. in Biological Sciences section of this Catalog.

| | | |
|--|--|-------|
| Mathematics, Statistics, Physics and Computer Science | | Units |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-124 | Calculus II for Biologists and Chemists | 10 |
| or 21-122 Integration and Approximation | | |
| 36-200 | Reasoning with Data | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 Statistical Concepts and Methods for Behavioral and Social Science | | |
| 33-121 | Physics I for Science Students ² | 12 |
| or 33-141 Physics I for Engineering Students | | |
| 15-110 | Principles of Computing | 10-12 |
| or 15-112 Fundamentals of Programming and Computer Science | | |
| 99-101 | Computing @ Carnegie Mellon | 3 |

Total Science units 63-65

² MCS students must also complete 33-122 Physics II for Biological Sciences & Chemistry Students.

| | | |
|-----------|---|-------|
| Chemistry | | Units |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |

Total Chemistry units 56

| | | |
|--|--|-------|
| Psychology Courses | | Units |
| 85-102 | Introduction to Psychology | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-2xx | Survey Psychology Courses * | 18 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| or 85-314 Cognitive Neuroscience Research Methods | | |
| or 85-320 Research Methods in Developmental Psychology | | |
| or 85-330 Analytic Research Methods | | |
| or 85-340 Research Methods in Social Psychology | | |
| 85-3xx | Advanced Psychology Electives | 18 |

Total Psychology units 63

* Excluding 85-261 Psychopathology

Additional Advanced Elective 9 units

(Choose one of the following courses)

| | | |
|--------|------------------------------|---|
| 85-3xx | Advanced Psychology Elective | 9 |
| or | | |
| 03-3xx | Advanced Biology Elective | 9 |

Additional Laboratory or Research Methods 9-12 units

(Choose one of the following courses)

| | | |
|--------|--|----|
| 03-344 | Experimental Biochemistry | 12 |
| 03-345 | Experimental Cell and Developmental Biology | 12 |
| 03-346 | Experimental Neuroscience | 12 |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

| | | |
|---|--|-------|
| Elective Units | | Units |
| Free Electives | | 33-36 |
| MCS Nontechnical Breadth or DC General Education requirements | | 36-48 |

Total Elective units 69-84

Minimum number of units required for degree: 360

Bachelor of Science in Music and Technology

The Bachelor of Science in Music and Technology is offered jointly by the School of Music, the School of Computer Science, and the College of Engineering.

This program consists of a set of courses that span both music and technology, as well as a capstone composition/design/performance project. Courses in all three areas of study are stipulated in the music and technology undergraduate curriculum and provide for students coming from any of the three areas. In other words, regardless of a student's entry point — an interest in computer science, electrical engineering, or music — the coursework prescribed will allow the student to gain the requisite knowledge and experience in all three areas. Students will work closely with advisors and will be guided in both course selection and capstone projects.

Curriculum

Minimum units required for B.S. in Music and Technology 380

General Requirements 85 units

Seminar

57-570 Music and Technology Seminar 1
(8 semesters for a total of 8 units)

University

99-101 Computing @ Carnegie Mellon 3
76-101 Interpretation and Argument 9
xx-xxx Global, Cultural, and Diverse Perspectives Course 9

Humanities

xx-xxx Cognition, Choice and Behavior course 9
xx-xxx English, History, Modern Languages, Philosophy, or Psychology course 9

Mathematics

21-120 Differential and Integral Calculus 10
21-122 Integration and Approximation 10

Science

33-114 Physics of Musical Sound 9
33-141 Physics I for Engineering Students 12

Electives 33 or 37 units

Music Core 81 units

57-152 Harmony I 9
57-153 Harmony II 9
57-408 Form and Analysis 6
57-151 Counterpoint in Theory and Application 6
57-258 20th-21st Century Techniques 6
57-257 Orchestration I 6
57-189 Introduction to Repertoire and Listening for Musicians 3
57-190 Repertoire and Listening for Musicians I 3
57-289 Repertoire and Listening for Musicians II 3
57-290 Repertoire and Listening for Musicians III 3
57-181 Solfege I 3
57-182 Solfege II 3
57-183 Solfege III 3
57-184 Solfege IV 3
57-161 Eurhythmics I 3
57-162 Eurhythmics II 3
57-173 Survey of Western Music History 9

Music and Technology Core 121 units

15-112 Fundamentals of Programming and Computer Science 12

15-122 Principles of Imperative Computation 12
15-322 Introduction to Computer Music 9
18-100 Introduction to Electrical and Computer Engineering 12
18-202 Mathematical Foundations of Electrical Engineering 12
18-290 Signals and Systems 12
57-101 Introduction to Music Technology 6
57-347 Electronic and Computer Music 6
57-337 Sound Recording 6
57-338 Sound Editing and Mastering 6
57-438 Multitrack Recording 9
57-571 Music and Technology Project 12
57-572 Music and Technology Project 12

Concentration

Students complete either the Music Concentration or the Technical Concentration:

Music Concentration 60 units

57-5xx Studio (4 semesters) 36
57-4xx Major Ensemble (4 semesters) 24

Technical Concentration 58 or 56 units

21-127 Concepts of Mathematics 12
15/18-213 Introduction to Computer Systems 12

AND EITHER:

18-220 Electronic Devices and Analog Circuits 12
18-240 Structure and Design of Digital Systems 12
15-2xx/18-3xx Electives in ECE or CS or above 12

OR:

15-210 Parallel and Sequential Data Structures and Algorithms 12
15-323 Computer Music Systems and Information Processing 9
15-2xx/18-3xx Electives in ECE or CS or above 12

Bachelor of Science in Neuroscience

Veronica Hinman, *Department Head, Biological Sciences*

Michael Tarr, *Department Head, Psychology*

www.cmu.edu/ni (<https://www.cmu.edu/ni/>)

Neuroscience is an interdisciplinary field in which scientists from many backgrounds apply the tools of biology, cognitive science, psychology, chemistry, mathematics, statistics, computer science, and engineering to develop a comprehensive understanding of brain function at the level of molecules, neurons, brain circuits, cognitive brain modules, and behavior. Research in neuroscience across these disciplines has grown substantially in the past two decades, and a solid understanding of the physiological basis of many aspects of brain function both in health and disease has come along with this growth in research. Along with this comes an increasing need for students to begin careers in neuroscience and to be prepared to work on the problems in neuroscience and to bring new answers to the public and to patients. In order to be successful in developing new treatments and answering outstanding questions in the field, neuroscientists need to be conversant in many different levels of inquiry from neurobiology to cognitive neuroscience to computational neuroscience.

The Dietrich College of Humanities & Social Sciences and the Mellon College of Science have joined forces to establish an exciting interdisciplinary program leading to a Bachelor of Science in Neuroscience. The goal of this degree program is to provide an intensive interdisciplinary education to enable outstanding students to become leaders in identifying and solving tomorrow's Neuroscience problems using a variety of methods. The program's interdisciplinary curriculum is designed for students to gain a fundamental understanding of brain function on many different levels and to begin to specialize within the broad field of Neuroscience. Students in Mellon College of Science or Dietrich College may have a primary major in Neuroscience in any of the three concentrations. Students from other colleges may have a

second major in Neuroscience in any of the three concentrations, subject to double-counting restrictions.

A degree in neuroscience provides excellent preparation for medical school or other graduate programs in the health professions. These students are aided by the Carnegie Mellon Health Professions Program (HPP), an advisory and resource service for all Carnegie Mellon students who are considering careers in the health care field. (See the HPP (p. 20) section in this catalog or www.cmu.edu/hpp (<http://www.cmu.edu/hpp/>) for more information.)

Students wishing to pursue the Neuroscience major through Dietrich College should contact Dr. Lori Holt (loriholt@cmu.edu). Students wishing to pursue the Neuroscience major through the Mellon College of Science should contact the Biological Sciences Undergraduate Programs Office (bio-ugrad@andrew.cmu.edu). Students wishing to pursue an additional major in either the Neurobiology or Computational Neuroscience concentrations should contact the Biological Sciences Undergraduate Programs Office (bio-ugrad@andrew.cmu.edu). Students wishing to pursue an additional major in the Cognitive Neuroscience concentration should contact Dr. Lori Holt (loriholt@cmu.edu).

Students who pursue this major will:

- Gain a broad understanding of Neuroscience at many different levels of analysis, including: cellular biology of the brain, brain systems, cognitive brain function, and computational brain modeling
- Gain an understanding of the sciences underlying Neuroscience, including: Biology, Chemistry, Computer Science, Cognition and Psychology, and other emerging areas
- Develop a comprehensive understanding of brain function in health and disease
- Be familiar with neuroanatomy & neurophysiology and their implications for nervous system function
- Be prepared for advanced study in neurobiology, cognitive neuroscience, and/or neural computation
- Be able to collaborate with Neuroscientists across a wide range of systems and levels of analysis
- Prepare for careers in Neuroscience related companies, Neuroscience research, and/or medicine
- Be prepared for specialization within subfields of Neuroscience given their concentration selection

Requirements for a B.S. in Neuroscience

All students must complete the following:

1. General Science Requirements (see section A)
2. Core Neuroscience Courses (see section B)
3. Requirements for one concentration (see sections C, D, or E)*
4. 18 additional relevant course units in their home concentration or other neuroscience areas (some examples listed in sections C, D, E, & F). At least 9 of these units must be at the 300-level or above.
5. Their home college's General Education requirements
6. Free elective units to come to a total of 360 total course units

* Double-counting restrictions and additional majors & minors

- Students may not major in two concentrations.
- Students using Neuroscience as an additional major or who have an additional major or minor to Neuroscience may only double-count at most 3 courses between this and their other major or minor (this restriction does not apply to prerequisites, General Education Requirements, or the General Science Requirements - section A).
- Other majors and minors may have more stringent double-counting restrictions, please consult with your neuroscience advisors and with the advising staff for the relevant host department for the other majors/minors.

A. General Science Requirements

| | Units |
|--|-------|
| 21-120 Differential and Integral Calculus | 10 |
| 21-122 Integration and Approximation | 10 |
| or 21-124 Calculus II for Biologists and Chemists | |
| 03-121 Modern Biology | 9 |
| or 03-151 Honors Modern Biology | |
| 03-201 Undergraduate Colloquium for Sophomores | 1 |
| 03-220 Genetics | 9 |
| or 03-221 Genomes, Evolution, and Disease: Introduction to Quantitative Genetic Analysis | |

| | |
|---|-------|
| 09-105 Introduction to Modern Chemistry I | 10 |
| 09-106 Modern Chemistry II | 10 |
| 09-207 Techniques in Quantitative Analysis ¹ | 9-12 |
| or 09-221 Laboratory I: Introduction to Chemical Analysis | |
| or 03-124 Modern Biology Laboratory | |
| 09-217 Organic Chemistry I ¹ | 9 |
| or 33-122 Physics II for Biological Sciences & Chemistry Students | |
| 33-121 Physics I for Science Students | 12 |
| 15-110 Principles of Computing ² | 10-12 |
| or 15-112 Fundamentals of Programming and Computer Science | |
| 36-200 Reasoning with Data ² | 9 |
| or 36-218 Probability Theory for Computer Scientists | |
| or 36-219 Probability Theory and Random Processes | |
| or 36-225 Introduction to Probability Theory | |
| 99-101 Computing @ Carnegie Mellon | 3 |

111-116

¹ Neurobiology concentration students are required to complete 09-217 & 09-207 or 09-221.

² Computational Neuroscience concentration students are required to complete 21-122, 15-112, & 36-218 or 36-219

B. Core Neuroscience Courses

| | Units |
|--|-------|
| 85-219 Foundations of Brain and Behavior | 9 |
| or 03-161 Molecules to Mind | |
| 85-211 Cognitive Psychology | 9 |
| or 85-213 Human Information Processing and Artificial Intelligence | |
| 03-362 Cellular Neuroscience | 9 |
| 03-363 Systems Neuroscience | 9 |
| 15-386 Neural Computation ³ | 9 |
| or 85-419 Introduction to Parallel Distributed Processing | |
| or 02-319/03-360 Genomics and Epigenetics of the Brain | |
| or 86-375 Computational Perception | |
| or 85-435 Biologically Intelligent Exploration | |

45

³ Computational Neuroscience concentration students are required to complete 15-386.

C. Neurobiology Concentration

| Didactic Core: Students must complete all of the following* | | Units |
|---|--|-------|
| 03-231 Honors Biochemistry | | 9 |
| 03-320 Cell Biology | | 9 |

18

* Neurobiology concentration students must complete 09-217 & 09-207 or 09-221 in their General Science Requirements (section A, above)

| Required laboratory, data analysis, & methodological courses | | Units |
|--|--|-------|
| 03-343 Experimental Techniques in Molecular Biology | | 12 |
| 03-346 Experimental Neuroscience | | 12 |
| or 03-345 Experimental Cell and Developmental Biology | | |

24

Electives in Neurobiology (minimum of 18 additional units, at least 9 units at 300-level or above)**

| | |
|---|----|
| 03-133 Neurobiology of Disease | 9 |
| 02-250 Introduction to Computational Biology | 12 |
| 03-350 Developmental Biology | 9 |
| 03-365 Neural Correlates of Learning and Memory | 9 |
| 03-366 Neuropharmacology: Drugs, Brain and Behavior | 9 |
| 03-439 Introduction to Biophysics | 10 |
| 03-442 Molecular Biology | 9 |
| 09-218 Organic Chemistry II | 9 |
| 09-208 Techniques for Organic Synthesis and Analysis | 9 |
| or 09-222 Laboratory II: Organic Synthesis and Analysis | |

| | | |
|--------|--|---|
| 42-202 | Physiology | 9 |
| 42-203 | Biomedical Engineering Laboratory NOTE: VERY Limited Seating Available for 42-203 | 9 |

** At least 9 of these units must be 300-level or above

D. Cognitive Neuroscience Concentration

| | | |
|--|--|-----------|
| Didactic Core. Students must complete all of the following | | Units |
| 85-102 | Introduction to Psychology | 9 |
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| | | 18 |

| | | |
|--|--|-----------|
| Required laboratory, data analysis, & methodological courses | | Units |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| | | 18 |

| | | |
|--|---|-------|
| Electives in Cognitive Neuroscience (minimum of 27 additional hours)** | | Units |
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-261 | Psychopathology | 9 |
| 85-356 | Expertise: The cognitive (neuro)science of mastering almost any skill | 9 |
| 85-370 | Perception | 9 |
| 85-406 | Autism: Psychological and Neuroscience Perspectives | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing * | 9 |
| 85-424 | Hemispheric Specialization: Why, How and What? | 9 |
| 85-426 | Learning in Humans and Machines | 9 |
| 85-429 | Cognitive Brain Imaging | 9 |
| 85-442 | Health Psychology | 9 |
| 85-501 | Readings in Developmental psychology | 9 |

* If not used as a core course

** At least 18 of these units must be 300-level or above

E. Computational Neuroscience Concentration

Strong candidates for the Computational Neuroscience Concentration will have earned a B average in 21-127, 21-241, 15-112, and 15-122. We strongly recommend meeting with your advisor to discuss interest in this major and for help planning appropriate schedules to support student success.

| | | |
|---|--|-----------|
| Didactic Core. Students must complete all of the following* | | Units |
| 21-127 | Concepts of Mathematics | 12 |
| 15-122 | Principles of Imperative Computation or 15-150 Principles of Functional Programming | 12 |
| 21-241 | Matrices and Linear Transformations or 21-240 Matrix Algebra with Applications | 10 |
| | | 34 |

* Computational Neuroscience concentration students must complete 21-122, 15-112, and 36-218 or 36-219 in their General Science Requirements (section A, above) and 15-386 in their Core Neuroscience Courses (section B, above). Students must complete a minimum of 60 units in this concentration. Students should select their required laboratory and elective courses to complete a minimum of 31 units (Four 9 unit courses or a lesser number of 9 and 12 unit courses could be combined to complete this requirement).

| | | |
|--|--|-------|
| Required laboratory, data analysis, and methodological courses (18-24 total units) | | Units |
| 42/86-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 15-883 | Computational Models of Neural Systems | 12 |

| | | |
|--------|---|---|
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

| | | |
|--|--|-------|
| Electives in Computational Neuroscience (minimum of 9 units) | | Units |
| 03-360/02-319 | Genomics and Epigenetics of the Brain | 9 |
| 02-512 | Computational Methods for Biological Modeling and Simulation | 9 |
| 10-301 | Introduction to Machine Learning (Undergrad) or 10-315 Introduction to Machine Learning (SCS Majors) or 10-601 Introduction to Machine Learning (Master's) | 12 |
| 15-387 | Computational Perception | 9 |
| 15-451 | Algorithm Design and Analysis | 12 |
| 15-453 | Formal Languages, Automata, and Computability | 9 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 15-883 | Computational Models of Neural Systems | 12 |
| 16-299 | Introduction to Feedback Control Systems | 12 |
| 16-311 | Introduction to Robotics | 12 |
| 21-228 | Discrete Mathematics | 9 |
| or 15-251 | Great Ideas in Theoretical Computer Science | |
| 21-259 | Calculus in Three Dimensions | 10 |
| 21-341 | Linear Algebra | 9 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-350 | Statistical Computing | 9 |
| 36-401 | Modern Regression | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 42/86-631 | Neural Data Analysis | 12 |
| 42-632 | Neural Signal Processing | 12 |
| 42-688 | Introduction to Neural Engineering | 12 |

F. Additional Neuroscience Electives

Students are required to take a minimum of 18 additional relevant course units beyond those required for the concentration. These electives can be additional coursework from their home concentration or other neuroscience areas. Some examples are listed in sections C, D, & E above as well as in the list below. At least 9 of these additional 18 units must be at the 300-level or above.

NOTE: this list is not restrictive. Concentration advisors can approve additional elective courses that contribute to the student's neuroscience education, subject to additional approval by the major steering committee.

Examples of Additional Electives relevant to major*

| | | |
|--------|---|---|
| 33-122 | Physics II for Biological Sciences & Chemistry Students <small>unless used for Science Core (section A)</small> | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-220 | Philosophy of Science | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 88-355 | Social Brains: Neural Bases of Social Perception and Cognition | 9 |

* Up to 9 units of applicable undergraduate research course work (e.g. 03-445 or 85-507/85-508) can count as a neuroscience elective (not towards a concentration). A maximum of 27 additional units can be counted as a free electives.

| | |
|--|--------------|
| Free Electives (depending on concentration & college) | 51-61 |
| TOTAL hours to degree | 360 |

BXA Intercollege Degree Programs

M. Stephanie Murray, Senior Associate Dean of Interdisciplinary Initiatives
Location: Hall of the Arts 211
www.cmu.edu/interdisciplinary (<http://www.cmu.edu/interdisciplinary/>)

Mission Statement

The BXA Intercollege Degree Programs are designed for students who want to turn talent and passion into viable professions for the future through a challenging academic curriculum. BXA students pursue their goals with the help of multifaceted advising, innovative pedagogical strategies and a focus on the impact arts have on technology and vice versa.

The goal of the Bachelor of Computer Science and Arts (BCSA), the Bachelor of Engineering Studies and Arts (BESA), the Bachelor of Humanities and Arts (BHA), the Bachelor of Science and Arts (BSA) and the additional major in Engineering and Arts (EA), housed under the BXA Intercollege Degree Programs, is to allow a select group of students who demonstrate interest and accomplishment in the fine arts and computer science, engineering, humanities, social sciences or natural sciences to explore beyond the traditional academic major, or integrate more than one field of study across disciplines. These programs foster the creativity of students who explore innovative approaches to the academic environments of two colleges. By merging the components in the arts and computer science, engineering, natural sciences or humanities into an interdisciplinary/multidisciplinary study, a unique, complex product is born. BXA students produce new information, challenging questions and innovative theory. BXA students are models of independence, motivation and well-rounded scholarship as humanists, scientists and artists at the same time.

In the context of the Carnegie Mellon University environment, the BXA Intercollege Degree Programs hold a special role. BXA provides access to five strong colleges that offer specialized training with expert faculty and researchers. The BXA Programs challenge students to utilize those resources as they explore and develop their own approach to interdisciplinary studies in the fine arts and computer science, engineering, humanities and social sciences, or the natural and mathematical sciences.

BXA students balance courses in their CFA concentration with courses in their academic concentration, as well as BXA-specific courses. These BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques. The curricula in the concentration areas provide students with a solid disciplinary foundation upon which they can draw for interdisciplinary projects.

A BXA intercollege degree prepares students for graduate study and careers in an enormous variety of fields, including traditional graduate training in the arts as well as academic areas, positions in arts and education non-profits such as museums and foundations, and technical positions with media and technology companies.

Program Objectives

The skills developed by BXA students span the creative, the technical, the academic and the practical. The objective of the BXA Intercollege Degree Programs is to prepare graduates for careers in which they will draw on their creative and academic skills to create, educate, communicate and innovate across disciplines.

Students who complete the BXA curriculum will graduate with the following skills:

- Foundational knowledge and technical expertise in the CFA concentration area and the DC/ENG/MCS/SCS concentration area
- Ability to describe the connections between these concentrations and how the student integrates them
- Ability to communicate ideas textually, visually and orally
- Knowledge of how the concentration disciplines intersect with history, society and culture from local and global perspectives
- Ability to use cognitive, behavioral and ethical dimensions within the concentration disciplines to make decisions on individual and social levels
- Experience in engaging in art research to produce new knowledge both within the CFA concentration and the DC/ENG/MCS/SCS concentration

- Experience in designing, researching and completing a large-scale, object-based project that integrates both areas of concentration

Bachelor of Computer Science and Arts Degree Program

The Bachelor of Computer Science and Arts (BCSA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the School of Computer Science (SCS). This degree provides an ideal technical, critical and conceptual foundation for students interested in pursuing fields that comprehensively meld technology and the arts, such as game design, computer animation, computer music, recording technologies, interactive stagecraft, robotic art and other emerging media. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their computer science concentration established by the School of Computer Science.

The BCSA curriculum has three main components: general education requirements, fine arts concentration requirements and computer science concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and SCS. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in SCS to guide their focus in computer science.

BCSA Curriculum

| | Units |
|---------------------------------------|----------------|
| I. BCSA General Education | 122 |
| II. SCS Concentration | 117 |
| III. CFA Concentration | 108-114 |
| IV. Free Electives | 27-33 |
| Total BCSA Degree Requirements | 380 |

BCSA General Education

(15 courses, 122 units minimum)

- Writing (1 course, 9 units, 76-101 required)
- Mathematics (2 courses, 20 units minimum, 21-122 and either 21-259, 21-266 or 21-241 required), Probability (1 course, 9 units minimum)
- Science & Engineering (2 courses, 18 units minimum)
- Economic, Political, & Social Institutions OR Cognition, Choice & Behavior (1 course, 9 units minimum)
- Two additional courses from Dietrich or CFA (2 course, 18 units minimum)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Writing (1 course, 9 units)

Broadly considered, language is a tool used to communicate, as well as a way to organize non-visual and non-mathematical thinking. This requirement focuses on the social nature of language and the ways in which writing constitutes thinking.

| | | |
|-----------|---|---|
| 76-101 | Interpretation and Argument | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |
| or 76-106 | Writing about Literature, Art and Culture | |
| & 76-107 | and Writing about Data | |
| & 76-108 | and Writing about Public Problems | |

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Mathematics & Probability (3 courses, 29 units minimum)

Choose two mathematics courses (20 units minimum):

| | | |
|-----------|---|----|
| 21-122 | Integration and Approximation | 10 |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-266 | Vector Calculus for Computer Scientists | |
| or 21-241 | Matrices and Linear Transformations | |

Choose one probability course(s) (9 units minimum):

| | | |
|---------------|--|----|
| 15-259 | Probability and Computing | 12 |
| 21-325 | Probability | 9 |
| 36-218 | Probability Theory for Computer Scientists | 9 |
| 36-225-36-226 | Introduction to Probability Theory - Introduction to Statistical Inference | 18 |

Science & Engineering (2 courses, 18 units minimum)

Choose two science courses from differing departments or one science and one engineering course from the following list:

| | | |
|---------------|---|------|
| 02-223 | Personalized Medicine: Understanding Your Own Genome | 9 |
| 03-121 | Modern Biology | 9 |
| 03-125 | Evolution | 9 |
| 03-132 | Basic Science to Modern Medicine | 9 |
| 03-133 | Neurobiology of Disease | 9 |
| 06-100 | Introduction to Chemical Engineering | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 12-201 | Geology | 9 |
| 18-095 | Getting Started in Electronics: An Experiential Approach | 9 |
| 18-100 | Introduction to Electrical and Computer Engineering | 12 |
| 24-101 | Fundamentals of Mechanical Engineering | 12 |
| 24-231 | Fluid Mechanics * | 10 |
| 24-291-24-381 | Environmental Systems on a Changing Planet - Environmental Systems on a Changing Planet: Science Engineering Addendum | 12 |
| 24-358 | Culinary Mechanics | 9 |
| 27-215 | Thermodynamics of Materials | 12 |
| 33-114 | Physics of Musical Sound | 9 |
| 33-120 | Science and Science Fiction | 9 |
| 33-121 | Physics I for Science Students * | 12 |
| 33-141 | Physics I for Engineering Students * | 12 |
| 33-151 | Matter and Interactions I * | 12 |
| 42-101 | Introduction to Biomedical Engineering | 12 |
| 42-202 | Physiology * | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| Labs: | | |
| 02-261 | Quantitative Cell and Molecular Biology Laboratory | Var. |
| 02-262 | Computation and Biology Integrated Research Lab | Var. |
| 27-100 | Engineering the Materials of the Future * | 12 |
| 33-104 | Experimental Physics | 9 |

Economic, Political & Social Institutions OR Cognition, Choice & Behavior (1 course from either category, 9 units minimum)

Economic, Political & Social Institutions

This requirement explores the processes by which institutions organize individual preferences and actions into collective outcomes.

| | | |
|------------|---|----|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 36-303 | Sampling, Survey and Society * | 9 |
| 66-221 | Topics of Law: Introduction to Intellectual Property Law | 9 |
| 70-332 | Business, Society and Ethics * | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere * | 9 |
| 79-101 | Making History: How to Think About the Past (and Present) | 9 |
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-244 | Women in American History | 9 |
| 79-253 | Imperialism and Decolonization in South Asia | 9 |
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-383 | The History of Capitalism | 9 |
| 79-391 | Nations and Nationalisms in South Asia | 9 |
| 79-392 | Europe and the Islamic World | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-334/335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-310 | International Political Economy * | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

Cognition, Choice, and Behavior

This requirement explores the process of thinking, decision making, and behavior in the context of the individual.

| | | |
|--------|---|---|
| 70-311 | Organizational Behavior * | 9 |
| 80-101 | Dangerous Ideas in Science and Society | 9 |
| 80-130 | Introduction to Ethics | 9 |
| 80-150 | Nature of Reason | 9 |
| 80-180 | Nature of Language | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-275 | Metaphysics | 9 |
| 80-330 | Ethical Theory | 9 |
| 85-102 | Introduction to Psychology | 9 |
| 85-104 | Psychopathology | 9 |
| 85-211 | Cognitive Psychology | 9 |

| | | |
|--------|--|---|
| 85-213 | Human Information Processing and Artificial Intelligence | 9 |
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |
| 85-261 | Psychopathology | 9 |
| 85-370 | Perception | 9 |
| 88-120 | Reason, Passion and Cognition | 9 |
| 88-230 | Human Intelligence and Human Stupidity | 9 |

* Indicates co-requisites and/or prerequisites required.

Additional Dietrich College Courses (2 courses, 18 units minimum)

Complete two non-technical courses. Consult with your BXA advisor to determine the best courses to fulfill this requirement.

University Requirement (1 course, 3 units)

This is a mini-course, pass/no pass, to be completed in the first semester or online in the summer prior to the first semester.

| | | |
|--------|-----------------------------|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
|--------|-----------------------------|---|

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

| | | |
|--------|--|-----|
| 52-190 | BXA Seminar I: Building the Wunderkammer - Spring, Freshman (mini-4) | 4.5 |
| 52-291 | BXA Seminar II: Transferring Knowledge -Spring, Sophomore (mini-3) | 4.5 |
| 52-392 | BXA Seminar III: Deconstructing Disciplines | 9 |
| 52-401 | BXA Seminar IV: Capstone Project Research | 9 |
| 52-402 | BXA Seminar V: Capstone Project Production | 9 |

School of Computer Science Concentration

Computer Science Concentration

(11 courses, 117 units minimum)

Prerequisite

| | | |
|--------|--|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
|--------|--|----|

Computer Science Core Requirements (5 courses, 60 units)

| | | |
|--------|--|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-210 | Parallel and Sequential Data Structures and Algorithms | 12 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Concepts of Mathematics (1 course, 12 units)

| | | |
|--------|--|----|
| 21-127 | Concepts of Mathematics (co-requisite for 15-122; prerequisite for 15-150) | 12 |
|--------|--|----|

Note: First-year BCSA students may opt for 15-151 if offered, in place of 21-127.

Applications Courses or CS Electives (5 courses, 45 units minimum)

Choose a minimum of five courses from SCS beyond the core requirements, 200-level or higher, not including 02-201, 02-223, 02-250, 02-261, 15-351, 16-223, 17-200, 17-333, 17-562. Listed below are suggested choices for these electives. Consult with the CS advisor if interested in courses not listed.

| | | |
|--------|---|----|
| 05-391 | Designing Human Centered Software | 12 |
| 05-418 | Design Educational Games | 12 |
| 10-335 | Art and Machine Learning | 12 |
| 11-291 | Applied Computational Intelligence Lab | 9 |
| 11-344 | Machine Learning in Practice | 12 |
| 11-411 | Natural Language Processing | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-322 | Introduction to Computer Music | 9 |

| | | |
|--------|---|----|
| 15-323 | Computer Music Systems and Information Processing | 9 |
| 15-365 | Experimental Animation | 12 |
| 15-388 | Practical Data Science | 9 |
| 15-415 | Database Applications | 12 |
| 15-451 | Algorithm Design and Analysis | 12 |
| 15-458 | Discrete Differential Geometry | 12 |
| 15-462 | Computer Graphics | 12 |
| 15-463 | Computational Photography | 12 |
| 15-464 | Technical Animation | 12 |
| 15-465 | Animation Art and Technology | 12 |
| 15-466 | Computer Game Programming | 12 |
| 15-494 | Cognitive Robotics: The Future of Robot Toys | 12 |
| 16-264 | Humanoids | 12 |
| 16-362 | Mobile Robot Algorithms Laboratory | 12 |
| 16-374 | IDEATe: Art of Robotic Special Effects | 12 |
| 16-384 | Robot Kinematics and Dynamics | 12 |
| 16-385 | Computer Vision | 12 |
| 16-423 | Designing Computer Vision Apps | 12 |
| 16-455 | IDEATe: Human-Machine Virtuosity | 12 |
| 16-465 | Game Engine Programming | 10 |
| 16-467 | Human Robot Interaction | 12 |
| 17-214 | Principles of Software Construction: Objects, Design, and Concurrency | 12 |
| 17-313 | Foundations of Software Engineering | 12 |
| 17-356 | Software Engineering for Startups | 12 |
| 17-437 | Web Application Development | 12 |

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-114 units minimum)

BCSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

| | | |
|-----------|---|-------|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year | 10-15 |
| or 48-095 | Spatial Concepts for Non-Architecture Majors | |
| 62-122 | Digital Media I -Fall, Freshman year | 6 |
| 62-125 | Drawing I -Fall, Freshman year | 6 |
| 62-123 | Digital Media II -Spring, Freshman year | 6 |
| 62-126 | Drawing II -Spring, Freshman year | 6 |
| 48-240 | History of World Architecture, I -Spring, Freshman year | 9 |
| 48-241 | History of Modern Architecture -Fall, Sophomore year | 9 |

Architecture Electives (56 units minimum)

A minimum of 56 additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

| | | |
|--------|-------------------------------------|---|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
|--------|-------------------------------------|---|

Foundation Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |

| | | |
|--------|---------------------------|----|
| 60-135 | Foundations: Sculpture II | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

Intermediate Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|------------------------------|----|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

| | | |
|--|-------------------------------------|----|
| 60-401/402 | Senior Studio | 10 |
| 60-403 | Senior Critique Seminar | 10 |
| Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) | | 10 |
| Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) | | 10 |
| Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) | | 10 |
| Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) | | 10 |
| 60-499 | Studio Independent Study (one only) | 10 |

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

| | | |
|--------|---------------------------------------|---|
| 60-107 | Foundations: Critical Studies -Spring | 9 |
| 60-3xx | Critical Studies Elective | 9 |

Review Requirement (1 required review, 0 units)

Complete required review:

| | | |
|--------|---|---|
| 60-200 | Sophomore Review -Spring (pass/no pass) | 0 |
|--------|---|---|

Design Concentration

(108 units minimum)

Design Required Courses (16 courses, 98 units)

| | | |
|---|---|---------|
| 51-101 | Studio: Survey of Design -Fall, First-year | 10 |
| 51-121 | Visualizing -Fall, First-year | 10 |
| 51-175 | Design Studies: Place -Fall, First-year (mini-1) | 5 |
| 51-177 | Design Studies: Histories -Fall, First-year (mini-2) | 5 |
| 51-102 | Design Lab -Spring, First-year | 10 |
| 51-122 | Collaborative Visualizing -Spring, First-year | 10 |
| 51-176 | Design Studies: Futures -Spring, First-year (mini-3) | 5 |
| 51-178 | Design Studies: Experience -Spring, First-year (mini-4) | 5 |
| 51-277 | Design Studies: Systems -Fall, Sophomore year (mini-1) | 5 |
| 51-279 | Design Studies: Cultures -Fall, Sophomore year (mini-2) | 5 |
| 51-282 | Design Studies: Persuasion -Spring, Sophomore year (mini-3) | 5 |
| 51-284 | Design Studies: Power -Spring, Sophomore year (mini-4) | 5 |
| Choose Two Studios -Fall, Sophomore year: | | 4.5+4.5 |
| 51-225 | Communications Studio I: Understanding Form & Context | 4.5 |
| or 51-245 Products Studio I: Understanding Form & Context | | |
| or 51-265 Environments Studio I: Understanding Form & Context | | |
| Choose Two Corresponding Labs -Fall, Sophomore year: | | 4.5+4.5 |
| 51-227 | Prototyping Lab I: Communications | 4.5 |
| or 51-247 Prototyping Lab I: Products | | |
| or 51-267 Prototyping Lab I: Environments | | |

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(108 units minimum)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Required Courses for All Concentration Options (4 courses, 19 units)

| | | |
|--------|--|---|
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II (prerequisite: 54-177) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (optional) | 6 |

Work with Drama Faculty Area Chair to Approve Concentration Option (**89** units minimum).

Design Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of **63** additional Design units must be approved by the Design faculty area chair. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 64 units)

| | | |
|---------------|---|----|
| 54-121-54-122 | Directing I: A Director's Mindset - Directing I: A Director's Preparation | 18 |
| 54-221-54-222 | Directing II: In the Studio - Directing II: In The Room | 18 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-517 | Directors Common Hour (four times) | 16 |

A minimum of **25** additional Directing units must be approved by the Directing faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 59 units minimum)

| | | |
|---------------|---|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-200-54-200 | Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled) | 2 |
| 54-xxx | Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more) | 18 |

A minimum of **30** additional Dramaturgy units must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of **63** additional PTM units must be approved by the PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

| | | |
|-----------|-----------------|---|
| 57-152 | Harmony I | 9 |
| or 57-149 | Basic Harmony I | |

Work with Music Advisor to Approve Concentration Option (99 units minimum).

Audio Recording & Production Required Courses (7 courses, 40 units)

| | | |
|-----------|--|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Choose **59** units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-161 | Eurhythmics I | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-427 | Advanced Seminar in Film Musicology | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-622 | Independent Study in Sound Recording Production | 3 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEATe minor may double-count up to two of the IDEATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (12 courses, 76 units)

| | | |
|-----------|--|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (12 courses, 76 units)

| | | |
|-----------|--|---|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |

| | | |
|--------|--|----|
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (7 courses, 47 units)

| | | |
|-----------|--|----|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 57-911 | Music Since 1945 | 9 |
| 57-616 | Independent Study in Sound Studies | 9 |

Choose 52 units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music (prerequisite: 15-112) | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-343 | Music, Technology, and Culture | 9 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music (prerequisite: 57-101 or 57-171) | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-438 | Multitrack Recording | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEATe minor may double-count up to two of the IDEATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 3-4 courses, 27-33 units minimum)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Engineering Studies and Arts Degree Program

The Bachelor of Engineering Studies and Arts (BESA) intercollegiate degree program combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This degree is tailored for students seeking to apply knowledge from dual fields to advance maker culture in novel and creative ways. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their engineering studies concentration established by the College of Engineering. Options within the concentration include: biomedical engineering, chemical engineering, civil & environmental engineering, electrical & computer engineering, materials science & engineering or mechanical engineering.

The BESA curriculum has three main components: general education requirements, fine arts concentration requirements and engineering studies concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and ENG. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in ENG to guide their focus in engineering studies.

BESA Curriculum

| | Units |
|---------------------------------------|----------------|
| I. BESA General Education | 92 |
| II. ENG Concentration | 93-120 |
| III. CFA Concentration | 108-114 |
| IV. Free Electives | 54-87 |
| Total BESA Degree Requirements | 380 |

BESA GENERAL EDUCATION

(11 courses, 92 units minimum)

- Writing (1 course, 9 units, 76-101 required)
- Mathematics (2 courses, 20 units, 21-120 and 21-122 required)
- Science and Technology (2 courses, 24 units, 15-112 and 33-141 required)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Writing (1 course, 9 units)

| | | |
|-----------|---|---|
| 76-101 | Interpretation and Argument | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |
| or 76-106 | Writing about Literature, Art and Culture | |
| & 76-107 | and Writing about Data | |
| & 76-108 | and Writing about Public Problems | |

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Mathematics (2 courses, 20 units)

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |

Science and Technology (2 courses, 24 units)

| | | |
|--------|--|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 33-141 | Physics I for Engineering Students | 12 |

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

| | | |
|--------|--|-----|
| 52-190 | BXA Seminar I: Building the Wunderkammer - Spring, Freshman (mini-4) | 4.5 |
| 52-291 | BXA Seminar II: Transferring Knowledge -Spring, Sophomore (mini-3) | 4.5 |
| 52-392 | BXA Seminar III: Deconstructing Disciplines | 9 |
| 52-401 | BXA Seminar IV: Capstone Project Research | 9 |
| 52-402 | BXA Seminar V: Capstone Project Production | 9 |

College of Engineering Concentration

(number of courses vary, 93-120 units)

BESA students declare one of the following concentrations, through consultation with their BXA advisor and the ENG concentration advisors. A completed ENG Concentration Declaration form must be approved by

the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's first year.

- Biomedical Engineering (93 units)
- Chemical Engineering (102 units)
- Civil Engineering (99 units)
- Electrical & Computer Engineering (120 units)
- Environmental Engineering (95 units)
- Materials Science & Engineering (99 units)
- Mechanical Engineering (105 units)

BESA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BESA students who are admitted through internal transfer must have chosen an ENG concentration at the time of their application (which serves as declaration). All BESA students wishing to change their ENG concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Biomedical Engineering Concentration

(93 units minimum)

Mathematics & Science Prerequisites

| | | |
|--------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 15-110 | Principles of Computing | 10 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 03-121 | Modern Biology | 9 |

Biomedical Engineering Courses (7 courses, 66 units)

| | | |
|--------|---|----|
| 42-101 | Introduction to Biomedical Engineering - Freshman year | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 42-202 | Physiology -Sophomore year; prereq: 03-121/03-151 | 9 |
| 42-203 | Biomedical Engineering Laboratory -Sophomore year; prereq: 42-101, 03-121/03-151 | 9 |
| 42-302 | Biomedical Engineering Systems Modeling and Analysis -Junior year; prereq: 06-262/18-202/21-260 | 9 |
| 42-401 | Foundation of BME Design -Fall, Senior year; prereq: 42-101 | 6 |
| 42-402 | BME Design Project -Spring, Senior year | 9 |

Electives (3 courses, 27 units minimum)

Choose 3 elective courses in BME tracks and/or ENG with prerequisites in consultation with the concentration advisor.

Chemical Engineering

(102 units minimum)

Mathematics & Science Prerequisites

| | | |
|--------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers -Fall, Sophomore year | 11 |
| 15-110 | Principles of Computing | 10 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 09-106 | Modern Chemistry II | 10 |

Chemical Engineering Courses (7 courses, 75 units)

| | | |
|--------|--|----|
| 06-100 | Introduction to Chemical Engineering -Freshman year; co-req: 09-105, 21-120 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 06-223 | Chemical Engineering Thermodynamics -Fall, Sophomore year; prereq: 06-100, 33-121/33-141/ 33-151 | 12 |

| | | | | | |
|--------|--|----|--------|---|----|
| 06-261 | Fluid Mechanics -Spring, Sophomore year; prereq: 06-223, 21-254 | 9 | 12-335 | Soil Mechanics -Fall, Junior year; prereq: 12-231, 33-142; co-req: 12-355 | 9 |
| 06-262 | Mathematical Methods of Chemical Engineering - Spring, Sophomore year; prereq: 06-223, 21-254 | 12 | 12-355 | Fluid Mechanics -Fall, Junior year; prereq: 21-260 | 9 |
| 06-323 | Heat and Mass Transfer -Fall, Junior year; prereq: 06-261, 06-262/21-260, 33-122/33-142/33-152 | 9 | 12-356 | Fluid Mechanics Lab -Fall, Junior year; co-req: 12-355 | 2 |
| 06-363 | Transport Process Laboratory -Spring, Junior year; prereq: 06-261, 06-323 | 9 | 12-351 | Environmental Engineering -Spring, Junior year; prereq: 09-105/09-111; co-req: 21-260 | 9 |
| | | | 12-635 | Structural Analysis -Fall, Senior year; prereq: 12-231 | 12 |
| | | | 12-631 | Structural Design -Spring, Senior year; prereq: 12-231; co-req: 27-357, 12-358 | 12 |

Electives (3 courses, 27 units minimum)

Choose 27 units from the following ChemE and/or ENG courses with prerequisites in consultation with the concentration advisor:

| | | |
|--------|---|---|
| 06-310 | Molecular Foundations of Chemical Engineering - Fall, Junior year; prereq: 06-223, 09-106 | 9 |
| 06-325 | Numerical Methods and Machine Learning for Chemical Engineering -Fall, Junior year; prereq: 06-262, 15-110/15-112 | 6 |
| 06-326 | Optimization Modeling and Algorithms -Fall, Junior year; prereq: 06-262 | 6 |
| 06-364 | Chemical Reaction Engineering -Spring, Junior year; prereq: 06-310, 06-323 | 9 |
| 06-607 | Physical Chemistry of Colloids and Surfaces - Senior year | 9 |
| 06-609 | Physical Chemistry of Macromolecules -Fall, Senior year | 9 |
| 27-xxx | Materials Science course | 9 |

Note: With advisor approval, electives can instead be other ChemE/ENG courses as long as they are taken in proper order to follow the required prerequisites, not allowing 06-421.

Civil Engineering

(99 units minimum)

Mathematics & Science Prerequisites

| | | |
|-----------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 15-110 | Principles of Computing | 10 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-111 | Nanolegos: Chemical Building Blocks | |

Civil Engineering Courses (9 courses, 72 units)

| | | |
|--------|---|----|
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World -Freshman year; co-req: 21-120, 33-141 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 12-200 | CEE Challenges: Design in a Changing World - Fall, Sophomore year; prereq: 12-100 | 9 |
| 12-212 | Statics -Fall, Sophomore year; co-req: 12-100, 21-122, 33-141 | 9 |
| 12-233 | CEE Infrastructure Systems in Action -Fall, Sophomore year; prereq: 12-100 | 2 |
| 12-231 | Solid Mechanics -Spring, Sophomore year; prereq: 12-212 | 9 |
| 12-234 | Sensing and Data Acquisition for Engineering Systems -Spring, Sophomore year | 4 |
| 12-271 | Computation and Data Science for Civil & Environmental Engineering -Spring, Sophomore year; prereq: 15-110/15-112, 21-120, 21-122, 33-141 | 9 |
| 27-357 | Introduction to Materials Selection -Spring, Junior year | 6 |

Electives (3 courses, 27 units minimum)

Choose 27 units from the following CivE courses with prerequisites in consultation with the concentration advisor:

| | | |
|--------|--|---|
| 12-201 | Geology -Sophomore year | 9 |
| 12-301 | CEE Projects: Integrating the Built, Natural and Information Environments -Fall, Junior year; prereq: 12-200, 12-271 | 9 |

Electrical & Computer Engineering

(120 units minimum)

Mathematics & Science Prerequisites

| | | |
|--------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-122 | Principles of Imperative Computation | 12 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |

Electrical & Computer Engineering Courses (7 courses, 84 units)

| | | |
|--------|---|----|
| 18-100 | Introduction to Electrical and Computer Engineering -Freshman year; co-req: 21-120 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 18-202 | Mathematical Foundations of Electrical Engineering -Sophomore year; prereq: 21-122 * | 12 |
| 18-213 | Introduction to Computer Systems -Sophomore year; prereq: 15-122 | 12 |
| 18-220 | Electronic Devices and Analog Circuits - Sophomore year; prereq: 18-100; co-req: 33-142 | 12 |
| 18-240 | Structure and Design of Digital Systems - Sophomore year; prereq: 18-100 | 12 |
| 18-290 | Signals and Systems -Sophomore year; prereq: 18-100 | 12 |

* This course can also be substituted by a combination of two of the following courses: 21-254, 21-259, 21-260, 21-241, 21-242, 21-268.

Electives (3 courses, 36 units minimum)

Choose 3 elective courses 18-3xx and above. At least 2 courses should be Area Courses from 1 of the 5 Areas within ECE and 1 course may be an additional Area Course from a second Area, a Coverage Course or ENG with prerequisites in consultation with the concentration advisor.

Environmental Engineering

(95 units minimum)

Mathematics & Science Prerequisites

| | | |
|-----------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 15-110 | Principles of Computing | 10 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| or 09-111 | Nanolegos: Chemical Building Blocks | |

Environmental Engineering Courses (10 courses, 77 units)

| | | |
|--------|--|----|
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World -Freshman year; co-req: 21-120, 33-141 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 12-200 | CEE Challenges: Design in a Changing World - Fall, Sophomore year; prereq: 12-100 | 9 |
| 12-221 | Environmental Chemistry and Thermodynamics - Fall, Sophomore year; prereq: 09-105/09-111 | 9 |

| | | |
|--------|---|---|
| 12-222 | Environmental Chemistry Laboratory -Fall, Sophomore year; co-req: 09-101, 12-221 | 3 |
| 12-271 | Computation and Data Science for Civil & Environmental Engineering -Spring, Sophomore year; prereq: 15-110/15-112, 21-120, 21-122, 33-141 | 9 |
| 12-351 | Environmental Engineering -Spring, Junior year; prereq: 09-105/09-111; co-req: 21-260 | 9 |
| 12-352 | Environmental Engineering Lab -Spring, Junior year; co-req: 12-351 | 3 |
| 12-355 | Fluid Mechanics -Fall, Junior year; prereq: 21-260 | 9 |
| 12-356 | Fluid Mechanics Lab -Fall, Junior year; co-req: 12-355 | 2 |

Electives (2 courses, 18 units minimum)

Choose 18 units from the following EE courses with prerequisites in consultation with the concentration advisor:

| | | |
|--------|---|---|
| 12-201 | Geology -Sophomore year | 9 |
| 12-301 | CEE Projects: Integrating the Built, Natural and Information Environments -Fall, Junior year; prereq: 12-200 and 12-271 | 9 |
| 12-353 | Environmental Biology and Ecology -Spring, Junior year | 9 |
| 12-612 | Intro to Sustainable Engineering -Fall, Senior year | 9 |
| 12-657 | Water Resource Systems Engineering -Fall, Senior year; prereq: 12-355; co-req: 12-351 | 9 |
| 03-121 | Modern Biology | 9 |

Materials Science & Engineering

(99 units minimum)

Mathematics & Science Prerequisites

| | | |
|--------|--|----|
| 21-120 | Differential and Integral Calculus -(Gen Ed) | 10 |
| 21-122 | Integration and Approximation -(Gen Ed) | 10 |
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 15-110 | Principles of Computing | 10 |
| 33-141 | Physics I for Engineering Students -(Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| 09-105 | Introduction to Modern Chemistry I | 10 |

Materials Science & Engineering Courses (8 courses, 72 units)

| | | |
|--------|---|----|
| 27-100 | Engineering the Materials of the Future - Freshman year; co-req: 21-120, 33-141 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 27-211 | Structure of Materials (Minor Option) -Fall, Sophomore year | 6 |
| 27-212 | Defects in Materials (Minor Option) -Spring, Sophomore year | 6 |
| 27-215 | Thermodynamics of Materials -Fall, Sophomore year; co-req: 27-100, 21-259 | 12 |
| 27-216 | Transport in Materials -Spring, Sophomore year; prereq: 27-215 | 9 |
| 27-227 | Phase Relations and Diagrams (Minor Option) - Spring, Sophomore year | 9 |
| 27-357 | Introduction to Materials Selection -Spring, Sophomore year | 6 |

* In consultation with the concentrations advisor, students may choose to complete the version of the course with lab component.

Electives (3 courses, 27 units minimum)

Choose 3 elective courses in MSE and/or ENG with prerequisites in consultation with the concentration advisor.

Mechanical Engineering

(105 units minimum)

Mathematics & Science Prerequisites

| | | |
|--------|--|----|
| 21-120 | Differential and Integral Calculus -Freshman year (Gen Ed) | 10 |
| 21-122 | Integration and Approximation -Freshman year (Gen Ed) | 10 |

| | | |
|--------|---|----|
| 21-254 | Linear Algebra and Vector Calculus for Engineers | 11 |
| 21-260 | Differential Equations | 9 |
| 15-110 | Principles of Computing -(Gen Ed) | 10 |
| 33-141 | Physics I for Engineering Students -Freshman year (Gen Ed) | 12 |
| 33-142 | Physics II for Engineering and Physics Students - Freshman year | 12 |

Note: The BESA Gen Ed Science and Technology requirement can be filled with either 15-110 or 15-112. Students may start taking MechE Courses upon completion of Calculus I, Calculus II and Physics I.

Mechanical Engineering Courses (7 courses, 60 units)

| | | |
|--------|--|----|
| 24-101 | Fundamentals of Mechanical Engineering - Freshman year; co-req: 21-120, 33-141 | 12 |
| xx-xxx | 2nd Introduction to Engineering course, student's choice | 12 |
| 24-200 | Maker Series: Intro to Manual Machining - Sophomore year | 1 |
| 24-251 | Electronics for Sensing and Actuation - Sophomore year | 3 |
| 24-261 | Mechanics I: 2D Design -Fall, Sophomore year; prereq: 21-122, 33-151/33-141/ 33-121/33-106 | 10 |
| 24-262 | Mechanics II: 3D Design -Spring, Sophomore year; prereq: 33-106/33-141/33-151, 24-261 | 10 |
| 24-370 | Mechanical Design: Methods and Application - Fall, Junior year; prereq: 24-200, 24-202, 24-262 | 12 |

Electives (45 units minimum)

Choose 5 elective courses. Each course should be a minimum of 9 units. At least 3 courses should be from the following MechE courses and 2 of the courses may be ENG with prerequisites in consultation with the concentration advisor.

| | | |
|--------|---|----|
| 24-221 | Thermodynamics -Fall; prereq: 21-122, 24-101, 33-106/33-121/33-141/33-151 | 10 |
| 24-231 | Fluid Mechanics -Spring; prereq: 21-122, 33-106/33-141/33-151 | 10 |
| 24-291 | Environmental Systems on a Changing Planet - Fall | 9 |
| 24-292 | Renewable Energy Engineering -Spring; prereq: 33-106/33-141 | 9 |
| 24-300 | or above | |

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-114 units minimum)

BESA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

| | | |
|-----------|---|-------|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year | 10-15 |
| or 48-095 | Spatial Concepts for Non-Architecture Majors | |
| 62-122 | Digital Media I -Fall, Freshman year | 6 |
| 62-125 | Drawing I -Fall, Freshman year | 6 |
| 62-123 | Digital Media II -Spring, Freshman year | 6 |
| 62-126 | Drawing II -Spring, Freshman year | 6 |
| 48-240 | History of World Architecture, I -Spring, Freshman year | 9 |
| 48-241 | History of Modern Architecture -Fall, Sophomore year | 9 |

Architecture Electives (56 units minimum)

A minimum of 56 additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

| | | |
|--------|-------------------------------------|---|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
|--------|-------------------------------------|---|

Foundation Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-135 | Foundations: Sculpture II | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

Intermediate Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|------------------------------|----|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

| | | |
|--|-------------------------------------|----|
| 60-401/402 | Senior Studio | 10 |
| 60-403 | Senior Critique Seminar | 10 |
| Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) | | 10 |
| Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) | | 10 |
| Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) | | 10 |
| Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) | | 10 |
| 60-499 | Studio Independent Study (one only) | 10 |

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

| | | |
|--------|---------------------------------------|---|
| 60-107 | Foundations: Critical Studies -Spring | 9 |
| 60-3xx | Critical Studies Elective | 9 |

Review Requirement (1 required review, 0 units)

Complete required review:

| | | |
|--------|---|---|
| 60-200 | Sophomore Review -Spring (pass/no pass) | 0 |
|--------|---|---|

Design Concentration

(108 units minimum)

Design Required Courses (16 courses, 98 units)

| | | |
|--------|---|----|
| 51-101 | Studio: Survey of Design -Fall, First-year | 10 |
| 51-121 | Visualizing -Fall, First-year | 10 |
| 51-175 | Design Studies: Place -Fall, First-year (mini-1) | 5 |
| 51-177 | Design Studies: Histories -Fall, First-year (mini-2) | 5 |
| 51-102 | Design Lab -Spring, First-year | 10 |
| 51-122 | Collaborative Visualizing -Spring, First-year | 10 |
| 51-176 | Design Studies: Futures -Spring, First-year (mini-3) | 5 |
| 51-178 | Design Studies: Experience -Spring, First-year (mini-4) | 5 |
| 51-277 | Design Studies: Systems -Fall, Sophomore year (mini-1) | 5 |
| 51-279 | Design Studies: Cultures -Fall, Sophomore year (mini-2) | 5 |
| 51-282 | Design Studies: Persuasion -Spring, Sophomore year (mini-3) | 5 |

| | | |
|--|--|---------|
| 51-284 | Design Studies: Power -Spring, Sophomore year (mini-4) | 5 |
| Choose Two Studios -Fall, Sophomore year: | | 4.5+4.5 |
| 51-225 | Communications Studio I: Understanding Form & Context | 4.5 |
| or 51-245 | Products Studio I: Understanding Form & Context | |
| or 51-265 | Environments Studio I: Understanding Form & Context | |
| Choose Two Corresponding Labs -Fall, Sophomore year: | | 4.5+4.5 |
| 51-227 | Prototyping Lab I: Communications | 4.5 |
| or 51-247 | Prototyping Lab I: Products | |
| or 51-267 | Prototyping Lab I: Environments | |

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(108 units minimum)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Required Courses for All Concentration Options (4 courses, 19 units)

| | | |
|--------|--|---|
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II (prerequisite: 54-177) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (optional) | 6 |

Work with Drama Faculty Area Chair to Approve Concentration Option (**89** units minimum).

Design Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of **63** additional Design units must be approved by the Design faculty area chair. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 64 units)

| | | |
|---------------|---|----|
| 54-121-54-122 | Directing I: A Director's Mindset - Directing I: A Director's Preparation | 18 |
| 54-221-54-222 | Directing II: In the Studio - Directing II: In the Room | 18 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-517 | Directors Common Hour (four times) | 16 |

A minimum of **25** additional Directing units must be approved by the Directing faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 59 units minimum)

| | | |
|---------------|---|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-200-54-200 | Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled) | 2 |
| 54-xxx | Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more) | 18 |

A minimum of **30** additional Dramaturgy units must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

| | | |
|---------------|--|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|--|----|

A minimum of **63** additional PTM units must be approved by the PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

| | | |
|-----------|-----------------|---|
| 57-152 | Harmony I | 9 |
| or 57-149 | Basic Harmony I | |

Work with Music Advisor to Approve Concentration Option (**99** units minimum).

Audio Recording & Production Required Courses (7 courses, 40 units)

| | | |
|-----------|---|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Choose **59** units from:

| | | |
|-----------|--|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-161 | Eurhythmics I | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-427 | Advanced Seminar in Film Musicology | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-622 | Independent Study in Sound Recording Production | 3 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (12 courses, 76 units)

| | | |
|-----------|---|---|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |

| | | |
|--------|--|----|
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (12 courses, 76 units)

| | | |
|-----------|---|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (7 courses, 47 units)

| | | |
|-----------|---|----|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 57-911 | Music Since 1945 | 9 |
| 57-616 | Independent Study in Sound Studies | 9 |

Choose 52 units from:

| | | |
|-----------|--|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music (prerequisite: 15-112) | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-343 | Music, Technology, and Culture | 9 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music (prerequisite: 57-101 or 57-171) | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-438 | Multitrack Recording | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

FREE ELECTIVES

(approximately 6-10 courses, 54-87 units minimum)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Humanities and Arts Degree Program

The Bachelor of Humanities and Arts (BHA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the Dietrich

College of Humanities and Social Sciences (DC). This degree is designed for academically and artistically talented students who want to develop their interest in the fine arts, while also pursuing studies in the humanities and social/behavioral sciences. Students choose their fine arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their humanities and social sciences concentration from the subject areas offered by DC. The most important aspect of the BHA program is for students to blend their interests and to explore the connections between their chosen disciplines. The program also provides enough flexibility for students to broaden or deepen their concentrations and to explore other areas in which they may be interested.

The BHA curriculum has three main components: general education requirements, fine arts concentration requirements and humanities/social sciences concentration requirements. Students must complete an array of courses defined by their chosen concentrations. Each student's course of study is unique, based on their background and interests, and course availability in the respective colleges.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and DC. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in DC to guide their focus in the humanities or social/behavioral sciences.

BHA Curriculum

| | Units |
|--------------------------------------|----------------|
| I. BHA General Education | 126 |
| II. DC Concentration | 81-107 |
| III. CFA Concentration | 108-114 |
| IV. Free Electives | 31-63 |
| Total BHA Degree Requirements | 378 |

BHA General Education

(16 courses, 126 units minimum)

- Communication (1 course, 9 units, 76-101 required)
- Contextual Thinking (1 course, 9 units)
- Intercultural and Global Inquiry (1 course, 9 units)
- Humanities (1 course, 9 units)
- Data Analysis (1 course, 9 units, 36-200 required)
- Social Sciences (1 course, 9 units)
- Equity and Justice (1 course, 9 units)
- Math, Science, and Computation (2 courses, 18 units)
- Disciplinary Perspectives within CMU (1 course, 6 units)
- University Requirement (1 course, 3 units, 99-101 required)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Communication (1 courses, 9 units)

| | | |
|-----------|---|---|
| 76-101 | Interpretation and Argument | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |
| or 76-106 | Writing about Literature, Art and Culture | |
| & 76-107 | and Writing about Data | |
| & 76-108 | and Writing about Public Problems | |

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

Contextual Thinking (1 course, 9 units)

A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Intercultural and Global Inquiry (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Humanities (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Data Analysis (1 course, 9 units minimum)

| | | |
|--------|---------------------|---|
| 36-200 | Reasoning with Data | 9 |
|--------|---------------------|---|

Social Sciences (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Equity and Justice (1 course, 9 units minimum)

A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Math, Science, and Computation (2 courses, 18 units minimum)

Choose two of three categories: Computational Thinking, Scientific Inquiry, Logic/Mathematical Reasoning. A list of courses for this requirement can be found on the DC GenEd website (<https://www.cmu.edu/dietrich/gened/fall-2021-and-beyond/course-options/>).

Disciplinary Perspectives within CMU (1 course, 6 units)

Choose one non-DC or CFA course; DC Arts courses excluded.

University Requirement (1 course, 3 units)

This is a mini-course, pass/no pass, to be completed in the first semester or online prior to the first semester.

| | | |
|--------|-----------------------------|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
|--------|-----------------------------|---|

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

| | | |
|--------|--|-----|
| 52-190 | BXA Seminar I: Building the Wunderkammer - Spring, Freshman (mini-4) | 4.5 |
| 52-291 | BXA Seminar II: Transferring Knowledge -Spring, Sophomore (mini-3) | 4.5 |
| 52-392 | BXA Seminar III: Deconstructing Disciplines | 9 |
| 52-401 | BXA Seminar IV: Capstone Project Research | 9 |
| 52-402 | BXA Seminar V: Capstone Project Production | 9 |

Dietrich College of Humanities and Social Sciences Concentrations

(number of courses vary, 81-93 units)

BHA students declare a DC concentration based on existing DC programs, through consultation with their BXA advisor and the DC concentration advisors. A completed DC Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's sophomore year.

Curriculum for approved BHA DC concentration options are outlined below, though this list is not exhaustive of all concentrations possible in DC.

BHA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BHA students who are admitted through internal transfer must have chosen a DC concentration at the time of their application (which serves as declaration). All BHA students wishing to change their DC concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Behavioral Economics Concentration

(81 units minimum)

Students in BE—the first and only major of its kind—will be uniquely trained in the integration of Economics and Psychology and will have a solid grounding in quantitative methods. The core includes courses in economics, psychology, behavioral economics, and quantitative methods. SDS offers the largest selection of behavioral economics courses anywhere in the world. Applied projects in courses will teach students how to collect original data, design field and laboratory experiments, analyze data, and develop interventions to improve economic outcomes and decisions. Students will be well equipped to enter a wide range of professions and graduate degree programs.

Quantitative Methods (3 courses, 27 units)

| | | |
|-----------|---------------------------------------|---|
| 36-202 | Methods for Statistics & Data Science | 9 |
| 88-251 | Empirical Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |
| or 73-274 | Econometrics I | |

Economics Courses (2 courses, 18 units)

| | | |
|-----------|---|---|
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 88-221 | Markets, Democracy, and Public Policy | 9 |
| or 73-103 | Principles of Macroeconomics | |
| or 73-158 | Markets, Models, and Math | |
| or 73-230 | Intermediate Microeconomics | |
| or 73-328 | Health Economics | |
| or 73-347 | Game Theory Applications for Economics and Business | |
| or 73-359 | Benefit-Cost Analysis | |
| or 73-408 | Law and Economics | |
| or 73-421 | Emerging Markets | |
| or 73-427 | Sustainability, Energy, and Environmental Economics | |

Psychology Courses (2 courses, 18 units)

| | | |
|--------|---|---|
| 88-120 | Reason, Passion and Cognition (freshman or sophomore year) | 9 |
| 88-302 | Behavioral Decision Making | 9 |

Behavioral Economics Courses (2 courses, 18 units)

| | | |
|-----------|---|---|
| 88-360 | Behavioral Economics (prerequisite: 21-111) | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| or 88-365 | Behavioral Economics and Public Policy | |

Chinese Studies Concentration*(81 units minimum)*

A BHA concentration in Chinese Studies promotes not just language proficiency but also an understanding of Chinese culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in Chinese. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in Chinese Studies (4 courses, 36 units minimum)

| | | |
|-----------|---|----|
| 82-232 | Intermediate Chinese II * | 12 |
| or 82-235 | Fables, Legends and Stories from Ancient Chinese Civilization | |
| 82-331 | Reading Into a New China I: Population, Youth, Marriage, & Housing | 9 |
| 82-332 | Reading Into a New China II: Transportation, Education, Pop Culture, & Health | 9 |
| 82-333 | Chinese Language and Culture | 9 |

*Students who place out of 82-232/82-235 must take a minimum of 9 additional units chosen from Chinese Studies Electives at the 400-level.

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|---|---|
| 82-239 | Crazy Linguistically Rich Asian Languages | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |

| | | |
|--------|--|---|
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in Chinese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

Core Courses in Chinese History & Society (1 course, 9 units)

Complete one course in consultation with the concentration advisor.

| | | |
|--------|---|---|
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| 82-138 | Comparative China: Perceptions Through Youtube & TikTok | 9 |
| 82-230 | Cultural Topics in Chinese Studies | 9 |
| 82-234 | Topics in Chinese History | 9 |
| 82-238 | Topics in Chinese Culture | 9 |
| 82-333 | Chinese Language and Culture (must be a different section than the one used for the core requirements) | 9 |

Chinese Studies and Interdisciplinary Electives (3 courses, 27 units minimum)

Complete two courses from Chinese Studies Electives and one course from Interdisciplinary Electives in consultation with the concentration advisor.

Chinese Studies Electives:

| | | |
|------------|---|------|
| 82-235 | Fables, Legends and Stories from Ancient Chinese Civilization | 9 |
| 82-334 | Structure of Chinese | 9 |
| 82-335 | Chinese Culture Through Legends and Folktales | 9 |
| 82-337 | Mandarin Chinese for Oral Communication I | 9 |
| 82-338 | Mandarin Chinese for Oral Communication II | 9 |
| 82-339 | Business Language & Culture in China I | 9 |
| 82-340 | Business Language & Culture in China II | 9 |
| 82-431 | China and the West | 9 |
| 82-432 | Chinese Popular Culture: A Game of Learning * | 9 |
| 82-433 | Topics in Contemporary Culture of China * | 9 |
| 82-434 | Studies in Chinese Traditions * | 9 |
| 82-436 | Introduction to Classical Chinese | 9 |
| 82-439 | Modern China Through Literature | Var. |
| 82-440 | Studies in Chinese Literature & Culture * | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-531/532 | Special Topics in Chinese Studies (independent studies) | Var. |
| 82-533 | Cultural Topics in Chinese Studies * | 6 |

* Students may repeat these courses with new topics.

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and the concentration advisor for the most up to date interdisciplinary electives appropriate for the Chinese Studies curriculum. Courses may be suggested to the concentration advisor for approval as a substitute. Note that not all courses are offered each semester.

| | |
|----------|---|
| Business | |
| 70-342 | Managing Across Cultures |
| 70-365 | International Trade and International Law |
| 70-430 | International Management |
| English | |
| 76-318 | Communicating in the Global Marketplace |
| 76-386 | Language & Culture |
| History | |

| | | |
|--|--|------|
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| Institute for Politics and Strategy (Choose in consultation with the concentration advisor.) | | |
| 84-226 | International Relations | 9 |
| 84-310 | International Political Economy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-405 | The Future of Warfare | 9 |
| Modern Languages | | |
| 82-137 | Chinese Calligraphy: Culture and Skills | 9 |
| 82-138 | Comparative China: Perceptions Through Youtube & TikTok | 9 |
| 82-139 | Topics in Chinese Language, Culture and Society | 9 |
| 82-198 | Research Training: Modern Languages | Var. |
| 82-230 | Cultural Topics in Chinese Studies | 9 |
| 82-234 | Topics in Chinese History | 9 |
| 82-238 | Topics in Chinese Culture | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-287 | Multicultural Immersion - Relating Your World in Virtual Reality | 6 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | |
| 80-180 | Nature of Language | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

Cognitive Neuroscience Concentration

(81 units minimum)

Cognitive neuroscience is a science concerned with discovering biological bases of psychological functions. It addresses questions of how behavior is produced by neural circuits of the brain and also how those neural circuits are in turn influenced by behavioral experiences. Students with a concentration in Cognitive Neuroscience are expected to learn about existing findings within the field and also to become proficient in how to conduct and analyze scientific investigations directed toward understanding the biological basis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses and writing reports.

Introductory and Survey Coursework (4 courses, 36 units)

| | | |
|-----------|--|---|
| 03-121 | Modern Biology | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-211 | Cognitive Psychology | 9 |
| or 85-213 | Human Information Processing and Artificial Intelligence | |

Research Methods Training (2 course, 18 units)

| | | |
|--------|--|---|
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
|--------|--|---|

| | | |
|-----------|--|---|
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |
| 85-314 | Cognitive Neuroscience Research Methods * | 9 |

* 85-310 *Research Methods in Cognitive Psychology* may be substituted if necessary.

Distribution Requirements (3 courses, 27 units)

Complete three courses with at least one from each category below.

Approaches to Cognitive Neuroscience:

| | | |
|--------|---|---|
| 15-386 | Neural Computation | 9 |
| 85-345 | Meaning in Mind and Brain | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-412 | Cognitive Modeling | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |

Cognitive Neuroscience Electives:

| | | |
|--------|--------------------------------------|---|
| 03-133 | Neurobiology of Disease | 9 |
| 03-362 | Cellular Neuroscience | 9 |
| 85-370 | Perception | 9 |
| 85-385 | Auditory Perception: Sense of Sound | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |
| 85-442 | Health Psychology | 9 |
| 85-443 | Social Factors and Well-Being | 9 |

Cognitive Science Concentration

(87 units minimum)

The field of cognitive science has grown out of increasingly active interaction among psychology, linguistics, artificial intelligence, philosophy, and neuroscience. All of these fields share the goal of understanding intelligence. By combining these diverse perspectives, students of cognitive science are able to understand cognition at a deep level. Because this concentration is administered by the Psychology Department, it focuses on human cognition and the experimental study of the human mind as illuminated by the techniques of the above disciplines.

Prerequisite Courses

| | | |
|--------------------|--|-------|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 21-120 | Differential and Integral Calculus | 10-20 |
| or 21-111 & 21-112 | Calculus I and Calculus II | |
| 21-127 | Concepts of Mathematics | 12 |

Statistics Course (1 course, 9 units)

| | | |
|-----------|--|---|
| 36-309 | Experimental Design for Behavioral & Social Sciences | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |

Computational/Cognitive Modeling Core (3 courses, 33 units)

Complete two of the following courses:

| | | |
|--------|---|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 15-251 | Great Ideas in Theoretical Computer Science | 12 |

Plus one of the following courses:

| | | |
|--------|---|---|
| 85-412 | Cognitive Modeling | 9 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |
| 85-435 | Biologically Intelligent Exploration | 9 |

Cognitive Psychology Core (4 courses, 36 units minimum)

| | | |
|-----------|--|---|
| 85-211 | Cognitive Psychology | 9 |
| or 85-213 | Human Information Processing and Artificial Intelligence | |
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| or 85-311 | Modern Research Methods: Cumulative Science, Big Data, and Meta-Analysis | |
| or 85-314 | Cognitive Neuroscience Research Methods | |

Plus two of the following (one of which must be 85-3xx or 85-4xx):

| | | |
|-----------|--|----|
| 85-219 | Foundations of Brain and Behavior | 9 |
| or 85-106 | Animal Minds | |
| 85-359 | Introduction to Music Cognition Research | 9 |
| 85-360 | Origins of Intelligence | 9 |
| 85-370 | Perception | 9 |
| 85-395 | Applications of Cognitive Science | 9 |
| 85-407 | How the Brain Makes Meaning | 9 |
| 85-408 | Visual Cognition | 9 |
| 85-414 | Cognitive Neuropsychology | 9 |
| 85-421 | Language and Thought | 9 |
| 80-310 | Formal Logic | 9 |
| 80-315 | Modal Logic | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |
| 05-413 | Human Factors | 9 |
| 11-344 | Machine Learning in Practice | 12 |

Cognitive Science Elective (1 course, 9 units)

Choose one elective in consultation with your concentration advisor.

Creative Writing Concentration

(81 units minimum)

In the Creative Writing concentration, BHA students develop their talents in writing fiction, poetry and other imaginative forms. While studying with faculty members who are practicing poets and prose writers, students read widely in literature, explore the resources of their imaginations, sharpen their critical and verbal skills and develop a professional attitude toward their writing. The Creative Writing program is based on a conservatory model, made up of faculty and students who have an intense commitment to their work.

Students in the Creative Writing concentration are required to take two of the introductory genre writing courses, ideally in their sophomore year. Choices include Introduction to Writing Poetry (76-265), Introduction to Writing Fiction (76-260), Introduction to Screenwriting (76-269) and Introduction to Writing Nonfiction (76-261). In order to proceed into the upper level courses in the concentration (and in each of the genres), students must do well in these introductory courses (receive a grade of A or B). After completing the introductory genre writing courses, students take four workshops in fiction, poetry, screenwriting or nonfiction. At least two of the workshops must be taken in a single genre. Workshops may be taken more than once for credit. In the writing workshops, students develop their critical and verbal abilities through close writing and analysis of poems, stories and other literary forms. Their work is critiqued and evaluated by peers and the faculty.

Survey of Forms Courses (2 courses, 18 units)

| | | |
|--------|---|---|
| 76-260 | Introduction to Writing Fiction | 9 |
| 76-261 | Introduction to Writing Creative Nonfiction | 9 |
| 76-265 | Introduction to Writing Poetry | 9 |
| 76-269 | Introduction to Screenwriting | 9 |

Note: A student must receive a grade of A or B in the Survey of Forms class in a specific genre in order to be eligible to enroll in a workshop of that genre. A student who receives a grade of C in a Survey of Forms course may enroll in a related workshop only with the permission of the workshop professor. A student who receives a D or R in Survey of Forms may not take a workshop in that genre.

Creative Writing Workshops (4 courses, 36 units)

Complete four Creative Writing workshops, at least two in a single genre. Workshops in all genres may be taken more than once for credit.

| | | |
|--------|------------------------------|---|
| 76-365 | Beginning Poetry Workshop | 9 |
| 76-460 | Beginning Fiction Workshop | 9 |
| 76-462 | Advanced Fiction Workshop | 9 |
| 76-464 | Creative Nonfiction Workshop | 9 |
| 76-465 | Advanced Poetry Workshop | 9 |
| 76-469 | Screenwriting Workshop | 9 |

English Electives (3 courses, 27 units)

Complete three courses (27 units minimum) from the English Department's offerings. Reading in Forms classes are recommended, as is 76-306 Editing and Publishing (note: this course is invitation only). Please consult the list of courses published each semester by the Department for current offerings. Students should discuss curriculum choices with the concentration advisor to determine the best electives for their focus in Creative Writing.

Cybersecurity & International Conflict

(81 units minimum)

The BHA concentration in cybersecurity and international conflict analyzes the past, present, and future role of cyber conflict and cybersecurity in international politics. Cyber attacks by nation-states and their proxies have an important impact upon conflict. The complexity and policy challenges of cyber-engagements is immense. This minor addresses the role of deterrence, dissuasion, and attribution in cyber conflict, while also studying the nuances of key components of modern warfare—from the security dilemma to escalation management.

Courses in this minor focus on the existing gaps in our understanding of cybersecurity and international conflict, such as whether cyberspace is offense or defense dominant (or over time fluid between the two), and which factors are important in determining the answer to this. Other relevant questions include how nation-states, their primary adversaries, and a bevy of nonstate actors engage online and in the virtual and information environments. Accordingly, the minor exposes students to basic technology concepts, methods of attack and defense, potential strategy and goals for cyber-engagement, and response and forensics for cyber-engagements.

Alongside conventional methods of warfare, cybersecurity has rapidly developed into a centerpiece of a state's ability to project power. As the United States and other emerging cyber powers craft and implement doctrine in this domain, there is likely to be a rapid increase in activity, from efforts to disrupt the online activities of global terrorist networks, to cybersecurity offense and defense in the Russia-Ukraine war, to near daily raids on foreign networks designed to cripple states' cyberweapons before they can be deployed. In addition, the impact of cyberattacks on critical infrastructure, theft of intellectual property, pervasive identity theft, and hacking of sensitive databases have accumulated, gradually wearing down civilian networks and achieving strategic effects over time.

In the shifting landscape of cyber capabilities, how will laws, authorities, and policies keep pace? What are the implications and consequences of actions that may be considered "short of war" by some countries but "above the threshold" of conflict by others? Will a more aggressive defensive posture with respect to cybersecurity inadvertently increase the risk of conflict with states that sponsor malicious hacking groups? What is the proper balance between offense and defense in cybersecurity and how are cyber operations best integrated into a country's overall military strategy?

Unlike other kinds of conflicts, attribution of attacks presents significant challenges. Indeed, in many cases, it can be difficult to determine whether the attacker is a nation-state, a nonstate actor, a criminal gang, or a lone hacktivist. Investigators must combine technical and traditional methods to identify potentially responsible parties and to understand their intent. If the aggressor's identity cannot be confirmed, how can a counterattack be launched? Some attackers may seek to mount "false flag" attacks and deception, for example, that misdirect defenders to counter-attack in the wrong direction.

Additionally, what are appropriate responses to attacks made on civil infrastructure and private business operations, such as in the areas of financial services, transportation, energy, entertainment, and health care? In other words, what are the appropriate rules of engagement for national systems, infrastructural systems, businesses, and individuals? When, for example, is a counterattack or a "kinetic" response permissible?

These questions have major implications for the study of war and peace. Those who seek to start a war may be harder to find and their motives more difficult to discern. The cybersecurity and international conflict minor tackles the social-scientific dimensions of cybersecurity with a focus on the implications of the cyber age for modern statecraft, warfare, elections (local, state, and national), and domestic and international politics.

Foundational Courses (2 courses, 18 units)

Students must complete two of the following courses:

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |

Core Courses (3 courses, 24 units)

| | | |
|--------|---|---|
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-405 | The Future of Warfare | 9 |

Electives (4-5 courses, 39 units minimum)

At least two courses (18 units) must be taken from the CMIST and have an 84-number.

| | | |
|--------|---|----|
| 84-200 | Security War Game Simulation | 6 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-319 | Civil-Military Relations | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 16-735 | Ethics and Robotics | 12 |
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 17-303 | Cryptocurrencies, Blockchains and Applications | 9 |
| 17-331 | Information Security, Privacy, and Policy | 12 |
| 17-333 | Privacy Policy, Law, and Technology | 9 |
| 17-334 | Usable Privacy and Security | 9 |
| 17-702 | Current Topics in Privacy Seminar | 3 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 95-444 | Cybersecurity Policy and Governance | 12 |

Decision Science Concentration

(84 units minimum)

Decision Science is grounded in theories and methods drawn from psychology, economics, philosophy, statistics, and management science. Courses in the BHA concentration in Decision Science cover the three aspects of decision science: (a) normative analysis, creating formal models of rational choice; (b) descriptive research, studying how cognitive, emotional, social, and institutional factors affect judgment and choice, and (c) prescriptive interventions, seeking to improve judgment and decision making. In addition to gaining a broad education in the principles of judgment and decision making, students with a concentration in Decision Science gain broadly applicable skills in research design and analysis. They also have the chance to think about and discuss decision making in many different areas.

Disciplinary Perspectives (5 courses, 48 units)

| | | |
|-----------|--|----|
| 73-102 | Principles of Microeconomics | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 85-102 | Introduction to Psychology | 9 |
| 88-120 | Reason, Passion and Cognition (freshman or sophomore year) | 9 |
| 88-223 | Decision Analysis | 12 |
| 88-302 | Behavioral Decision Making | 9 |

Research Methods (2 courses, 18 units)

| | | |
|-----------|--|---|
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 36-309 | Experimental Design for Behavioral & Social Sciences | |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |
| 88-251 | Empirical Research Methods | 9 |

Capstone (1 course, 9 units)

| | | |
|--------|---------------------------|---|
| 88-454 | Decision Science Capstone | 9 |
|--------|---------------------------|---|

Electives (1 course, 9 units minimum)

Complete one course (at least 9 units) from the following category of courses. Note that not all elective courses are offered every year.

Biological and Behavioral Aspects of Decision Making:

| | | |
|--------|---------------------------------------|---|
| 88-150 | Managing Decisions | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |

| | | |
|------------|--|----|
| 88-230 | Human Intelligence and Human Stupidity | 9 |
| 88-231 | Thinking in Person vs. Thinking Online | 9 |
| 88-252 | Cause and Effect | 9 |
| 88-255 | Strategic Decision Making | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |
| 88-312 | Decision Models and Games | 9 |
| 88-342 | The Neuroscience of Decision Making | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |
| 88-355 | Social Brains: Neural Bases of Social Perception and Cognition | 9 |
| 88-360 | Behavioral Economics | 9 |
| 88-365 | Behavioral Economics and Public Policy | 9 |
| 88-366 | Behavioral Economics of Poverty and Development | 9 |
| 88-367 | Behavioral Economics & Field Experiments in Organizations | 9 |
| 88-372 | Social and Emotional Brain | 9 |
| 88-380 | Dynamic Decisions | 9 |
| 88-388 | Psychological Models of Decision Making | 9 |
| 88-405 | Risk Perception and Communication | 9 |
| 88-406 | Behavioral Economics @ Work | 9 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| 88-419 | International Negotiation | 9 |
| 88-435 | Decision Science and Policy | 9 |
| 88-444 | Public Policy and Regulations | 9 |
| 88-451/452 | Policy Analysis Senior Project | 12 |

Economics Concentration

(81 units minimum)

The BHA concentration in Economics provides a solid understanding of economic theory and quantitative economic analysis. The core disciplinary sequences in economic theory and quantitative analysis are combined with calculus and data analysis to provide students with knowledge and skills that allow for creative problem-solving. Students pursuing the BHA concentration in Economics will hold a Dietrich College affiliation.

Mathematics Prerequisites

These courses are not counted as part of your DC Concentration. It may be used to satisfy general education or free elective requirements.

| | | |
|--------|------------------------------------|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-256 | Multivariate Analysis | 9 |

Economic Theory Requirements (4 courses, 36 units)

| | | |
|-----------|--|---|
| 73-102 | Principles of Microeconomics * | 9 |
| or 73-104 | Principles of Microeconomics Accelerated | |
| 73-103 | Principles of Macroeconomics | 9 |
| 73-230 | Intermediate Microeconomics | 9 |
| 73-240 | Intermediate Macroeconomics | 9 |

* Students who place out of 73-102 based on the economics placement exam will receive a prereq waiver for 73-102 and are waived from taking 73-102.

Quantitative Analysis Requirements (2 courses, 18 units)

These courses require 36-200 Reasoning with Data as a prerequisite. 36-200 also fulfills a general education Data Analysis requirement.

| | | |
|--------|----------------------------|---|
| 73-265 | Economics and Data Science | 9 |
| 73-274 | Econometrics I | 9 |

Advanced Economics Electives (2 courses, 18 units)

Students must take two advanced elective courses. Advanced elective courses are those numbered 73-300 through 73-495, as well as courses designated by the program offered by other departments/programs. Additionally, students may work with their economics advisor to structure alternative sets of courses to meet these requirements based on their particular interests, subject to course availability.

Senior Work (1 course, 9 units)

| | | |
|--------|----------------|---|
| 73-497 | Senior Project | 9 |
|--------|----------------|---|

Environmental & Sustainability Studies Concentration*(93 units minimum)*

The BHA concentration in Environmental & Sustainability Studies (ESS) focuses on human-environment interactions from a multitude of disciplinary perspectives. The curriculum draws on the expertise of faculty across several Carnegie Mellon colleges in order to provide students with the interdisciplinary background and skills necessary to understand environmental problems and the means to mitigate them. The curriculum is designed to help students apply social and scientific perspectives to environmental problems; to distinguish among scientific methods for evaluating environmental problems; to identify and assess sources of environmental data; and to identify environmental justice issues within the context of proposed policy solutions.

Core Courses (3 course, 27 units)

| | | |
|-----------|--|---|
| 24/09-291 | Environmental Systems on a Changing Planet | 9 |
| 66-236 | Introduction to Environmental Ideas | 9 |
| 66-506 | Senior Capstone (Interdisciplinary Research: Capstone in ESS) | 9 |

Earth and Environmental Science (1 course, 9 units)

Choose one course from the list below.

| | | |
|--------|--|---|
| 03-128 | Biology for Life Special Topics (Section S, Tropical Ecology) | 9 |
| 03-140 | Ecology and Environmental Science | 9 |
| 33-115 | Physics for Future Presidents | 9 |

Global Course (1 course, 3 units)

| | | |
|--------|--|---|
| 99-xxx | Each semester, a new course is offered on Global themes, in partnership with University of Pittsburgh's Global Studies Center. | 3 |
|--------|--|---|

Political Economy (1 course, 9 units minimum)

Choose one course from the list below.

| | | |
|--------|---|----|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 79-300 | History of American Public Policy | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-226 | International Relations | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |

Electives (5 courses, 45 units minimum)

Choose three DC Electives and two MCS/ENG Electives in consultation with the concentration advisor.

DC Electives:

| | | |
|--------|---|---|
| 76-241 | Introduction to Gender Studies | 9 |
| 76-291 | Getting Heard/Making a Difference | 9 |
| 76-354 | Watchdog Journalism | 9 |
| 76-395 | Science Writing * | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 79-201 | Introduction to Anthropology | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-297 | Technology and Work | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-372 | The Rise and Fall of Pittsburgh Steel | 6 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-383 | The History of Capitalism | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-244 | Environmental Ethics | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 85-241 | Social Psychology | 9 |

MCS/ENG Electives:

| | | |
|--------|---|----|
| 12-201 | Geology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |

| | | |
|--------|---|---|
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 27-505 | Exploration of Everyday Materials | 9 |
| 03-140 | Ecology and Environmental Science | 9 |

* *Additional prerequisite***Ethics, History, & Public Policy Concentration***(81 units minimum)*

The BHA concentration in Ethics, History, & Public Policy (EHPP) prepares students to be leaders is a vital goal of colleges and universities in every democratic society. The intellectual challenges facing public and private sector leaders have expanded dramatically since the pioneering EHPP program began in 1996, but the need remains as great as ever for broadly educated, ethically sensitive, and technically skilled leaders.

EHPP prepares students to demonstrate sophistication and flexibility in their command of interdisciplinary knowledge; deep historical understanding of how modern-day policy problems have emerged and evolved; and clear, rational criteria for ethical and socially just decision making. The curriculum provides students with a strong humanistic foundation for developing such high-level, historically grounded, and ethically attuned leadership capacities. It also offers ample room for specialization in a wide range of policy areas in which the History and Philosophy departments have special expertise, e.g., medicine and public health, criminal justice, environment, technology, artificial intelligence (AI), gender, civil rights, immigration, and education.

Foundation Courses in History and Philosophy (2 courses, 18 units)

Choose one of the following two courses:

| | | |
|--------|---|---|
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |

Choose one of the following two courses:

| | | |
|--------|------------------------|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-330 | Ethical Theory | 9 |

Ethics and Policy Core (3 courses, 27 units)

Choose three of the courses below:

No more than one course may be taken at the 100 level and at least one course must be taken at the 300 level or above.

| | | |
|--------|---|---|
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-208 | Critical Thinking | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

History and Policy Core (3 courses, 27 units)

Choose three of the courses below:

| | | |
|--------|---|---|
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-204 | American Environmental History | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-215 | Environmental Justice from Conservation to Climate Change | 9 |
| 79-234 | Technology and Society | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-278 | How (Not) to Change the World | 9 |

| | | |
|--------|--|---|
| 79-300 | History of American Public Policy | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-321 | Documenting Human Rights | 9 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-360 | Crime, Policing, and the Law: Historical and Contemporary Perspectives | 9 |
| 79-370 | Technology in the United States | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |

Foundation Courses in Law and Social Science (1 course, 9 units minimum)

Choose one of the courses below:

| | | |
|--------|---|----|
| 17-200 | Ethics and Policy Issues in Computing | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 70-332 | Business, Society and Ethics | 9 |
| 73-102 | Principles of Microeconomics | 9 |
| 73-103 | Principles of Macroeconomics | 9 |
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

Film & Visual Media Concentration

(81 units minimum)

The BHA concentration in Film & Visual Media trains students through a combination of coursework in visual media, film history and analysis, screenwriting, and production of film and other visual media. This concentration offers a comprehensive education in film and visual media, from theoretical framing and historical-cultural contextualization to training skills in both creating and analyzing film, and developing a complex blend of creative, professional and technical competencies. CMU's Department of English is an ideal home for the Film & Visual Media concentration due to the department's combination of creative writers, film and media studies scholars, film makers, digital humanities and visual communication researchers.

Introductory Courses (2 courses, 18 units)

| | | |
|--------|------------------------------|---|
| 76-239 | Introduction to Film Studies | 9 |
| 76-259 | Film History | 9 |

Production Course (1 course, 9 units)

| | | |
|--------|---------------------------------|---|
| 76-292 | Introduction to Film Production | 9 |
|--------|---------------------------------|---|

Screenwriting Course (1 course, 9 units)

| | | |
|--------|-------------------------------|---|
| 76-269 | Introduction to Screenwriting | 9 |
|--------|-------------------------------|---|

Topics in Film & Visual Media Studies (2 courses, 18 units)

Options include but are not limited to:

| | | |
|--------|---|---|
| 76-243 | Introduction to Television | 9 |
| 76-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 76-312 | Crime and Justice in American Film | 9 |
| 76-339 | Topics in Film and Media (Can be taken more than once.) | 9 |
| 76-353 | Transnational Feminisms: History and Film | 9 |
| 76-367 | Fact Into Film: Translating History into Cinema | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-449 | Race and Media | 9 |
| 76-454 | Rise of the Blockbuster | 9 |
| 79-225 | West African History in Film | 9 |
| 79-306 | Fact into Film: Translating History into Cinema | 9 |
| 79-308 | Crime and Justice in American Film | 9 |
| 79-319 | India Through Film | 6 |

| | | |
|--------|--|---|
| 79-326 | Shall We Dance? Culture, Politics, and Movement in the 20th Century | 6 |
| 79-339 | Juvenile Delinquency & Film: From Soul of Youth (1920) to West Side Story (1961) | 6 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |

Courses in Film Production, Screenwriting, Digital Media, Literature & Culture, and/or Film & Visual Media Studies (3 courses, 27 units)

Students may take an additional three Dietrich College courses for a minimum of 27 units of courses offered in the categories listed above. Because there are dozens of options available, including many of the courses listed above, please consult with the Department of concentration advisor for guidance. Recommended courses include 76-310 Advanced Studies in Film and Media, 76-323 Text to Screen, and 76-374 Mediated Narrative.

French & Francophone Studies Concentration

(81 units minimum)

A BHA concentration in French & Francophone Studies promotes not just language proficiency but also an understanding of French and francophone cultures. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in French. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in French & Francophone Studies (3 courses, 27 units)

| | | |
|------------|--|---|
| 82-303 | French & Francophone Cultures | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |
| 82-415/416 | Topics in French and Francophone Studies | 9 |

Note: 82-303 or 82-304 can be repeated with a different topic. A 400-level course may be substituted with the concentration advisor's approval.

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|--|---|
| 82-283 | Language Diversity & Cultural Identity | 9 |
|--------|--|---|

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in French & Francophone Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

French & Francophone Studies and Interdisciplinary Electives (5 courses, 45 units minimum)

Complete four courses from French & Francophone Electives and one course from Interdisciplinary Electives or three courses from French & Francophone Electives and two courses from Interdisciplinary Electives in consultation with the concentration advisor.

French & Francophone Studies Electives:

| | | |
|------------|--|------|
| 82-404 | Francophone Realities * | 9 |
| 82-415/416 | Topics in French and Francophone Studies * | 9 |
| 82-501/502 | Special Topics in French & Francophone Studies * | Var. |
| 82-505 | Modern Languages Undergraduate Internship | Var. |

* Students may repeat these courses with new topics.

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and the concentration advisor for the most up to date interdisciplinary electives appropriate for the French & Francophone Studies curriculum. Courses may be suggested to the

concentration advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|--|--|---|
| English | | |
| 76-239 | Introduction to Film Studies | 9 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-386 | Language & Culture | 9 |
| History | | |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-350 | Early Christianity | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| Institute for Politics and Strategy (Choose in consultation with the concentration advisor.) | | |
| 84-226 | International Relations | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-313 | International Organizations and Law | 6 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| Modern Languages | | |
| 82-227 | Germany & the European Union | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-288 | Everyday Learning: Designing Learning Exp in Times of Unrest & Uncertainty | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-380 | Philosophy of Language | 9 |
| 80-381 | Meaning in Language | 9 |
| Psychology | | |
| 85-241 | Social Psychology | 9 |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

German Studies Concentration

(81 units minimum)

A BHA concentration in German Studies promotes not just language proficiency but also an understanding of German culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in German. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in German Studies (4 courses, 36 units)

| | | |
|--------|--|---|
| 82-221 | Intermediate German I | 9 |
| 82-222 | Intermediate German II | 9 |
| 82-320 | Contemporary Society in Germany, Austria and Switzerland | 9 |

| | | |
|--------|--|---|
| 82-323 | Germany, Austria and Switzerland in the 20th Century | 9 |
|--------|--|---|

Note: If students have already completed the equivalent of the 200-level courses prior to arriving at Carnegie Mellon, they may take 400-level courses with approval from the concentration advisor. 400-level courses may also be substituted for the 300-level courses with the approval of the concentration advisor.

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|---|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in German Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

German Studies and Interdisciplinary Electives (4 courses, 36 units minimum)

Complete three courses from German Studies Electives and one course from Interdisciplinary Electives or two courses from German Studies Electives and two courses from Interdisciplinary Electives in consultation with the concentration advisor.

German Studies Electives:

| | | |
|------------|--|------|
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-425/426 | Topics in German Literature and Culture * | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-429 | German Reading and Translation Workshop: German in Today's World | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-521/522 | Special Topics in German Studies * | Var. |

* Students may repeat these courses with new topics.

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and the concentration advisor for the most up to date interdisciplinary electives appropriate for the German Studies curriculum. Courses may be suggested to the concentration advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|---------|--|---|
| English | | |
| 76-239 | Introduction to Film Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-387 | Writing in the Disciplines | 6 |
| 76-483 | Research Methods in Technical & Professional Communication | 9 |

| | | |
|---------|--|---|
| History | | |
| 79-205 | 20th Century Europe | 9 |
| 79-256 | Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990 | 9 |
| 79-257 | Germany and the Second World War | 9 |

Institute for Politics and Strategy (Choose in consultation with the concentration advisor.)

| | | |
|--------|---------------------------------|---|
| 84-226 | International Relations | 9 |
| 84-310 | International Political Economy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |

| | | |
|------------------|------------------------------|---|
| Modern Languages | | |
| 82-227 | Germany & the European Union | 9 |

| | | |
|------------|---|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-180 | Nature of Language | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-256 | Modern Moral Philosophy | 9 |
| 80-275 | Metaphysics | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

Global Studies Concentration

(81 units minimum)

The BHA concentration in Global Studies is designed for students interested in humanistic approaches to understanding past and present processes of globalization. Participating faculty in the departments of History, Modern Languages and English conduct research in Africa, Asia, Europe, Latin America, the Middle East and the Pacific. The rigorous yet flexible Global Studies curriculum combines anthropology, history, literary and cultural studies, and advanced language training in order to help students make sense of complex interactions among global processes, regional and local cultures, and societal structures. BHA concentration students in Global Studies develop a broad understanding of their prospects and responsibilities as citizens of the world confronting challenging contemporary problems.

There are two required courses for the concentration: Introduction to Global Studies (79-275) and Global Studies Research Seminar (79-400). Students also choose among several courses focused on theory, research methods, transnational histories, and regional/national histories and cultures.

In addition to coursework at Carnegie Mellon, BHA students with a concentration in Global Studies are encouraged to incorporate a semester of study abroad into their course of study in order to immerse themselves in society different from their own with unfamiliar cultural practices, language and history.

Students should consult frequently with the BHA advisor and the Global Studies concentration advisor who will help students to craft a coherent course of study on specific topics and/or regions that may lead to the capstone research project (79-400 Global Studies Research Seminar), the BXA capstone project (52-401 and 52-402) or a Dietrich College senior honors thesis (<https://www.cmu.edu/dietrich/students/undergraduate/programs/senior-honors/>). The concentration advisor will also work with students to connect their academic interests and their participation in student organizations and/or organizations based in Pittsburgh with transnational reach.

Global Studies Introductory and Capstone Courses (2 courses, 21 units)

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

| | | |
|--------|---------------------------------|----|
| 79-275 | Introduction to Global Studies | 9 |
| 79-400 | Global Studies Research Seminar | 12 |

Language Proficiency Requirement

Gaining skills in more languages is a crucial component of the major in Global Studies. Students will pursue **at least three semesters of language study**, no matter the level. That is, students could take three introductory courses in three different languages, or three different level

courses in the same language, or two different level courses in Language 1 and a third course in Language 2.

If students already know a language at an advanced level, they will take a test to certify those language skills. If they pass the test, they will need to take at least two semesters of language study, focused on a language different from the one they were tested on.

Please see the Modern Languages section of the schedule of classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>).

Theoretical and Topical Core Courses (2 courses, 18 units)

To gain a solid foundation in the theories, methods, and analytical topics underpinning the concentration in Global Studies, students select 18 units (typically two courses) from the core courses listed below. Students must earn a final grade of "C" or better in these courses to fulfill the theoretical and topical core course requirement.

| | | |
|--------|---|---|
| 79-201 | Introduction to Anthropology | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-289 | Animal Planet: An Environmental History of People and Animals | 9 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-315 | Thirsty Planet: The Politics of Water in Global Perspective | 9 |
| 79-317 | Art, Anthropology, and Empire | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-380 | Hostile Environments: The Politics of Pollution in Global Perspective | 9 |
| 79-383 | The History of Capitalism | 9 |

Transnational, Global, and Regional Courses (3 courses, 27 units)

To gain insight into how complex transnational and global processes shape and are affected by local, national and regional dynamics, students will select 27 units (typically three courses) from any subcategories below.

Transnational and Global Courses:

| | | |
|--------|---|---|
| 76-337 | Intersectional Feminism | 9 |
| 76-353 | Transnational Feminisms: Fiction and Film | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 79-149 | Ancient Rome: What Have the Romans Ever Done for Us? | 9 |
| 79-224 | Mayan America | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-270 | Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present | 9 |
| 79-273 | Jews and Muslims in History | 9 |
| 79-276 | Beyond the Border | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-282 | Europe and the World Since 1800 | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-333 | African Americans, Race, and the Fight for Reparations | 9 |
| 79-350 | Early Christianity | 9 |
| 79-368 | Un-natural Disasters: Societies and Environmental Hazards in Global Perspective | 6 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 79-510 | Global Studies Guided Reading | 3 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |

| | | |
|--------|--|---|
| 82-345 | Introduction to Hispanic Literary and Cultural Studies | 9 |
| 84-226 | International Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-389 | Terrorism and Insurgency | 9 |

Regional Courses:

Africa

| | | |
|--------|--|---|
| 79-225 | West African History in Film | 9 |
| 79-226 | African History: Earliest Times to 1780 | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-290 | The Slave Passage: From West Africa to the Americas | 9 |

Eastern and Southern Asia and the Pacific

| | | |
|--------|---|---|
| 79-207 | Asian American History through the Novel | 9 |
| 79-210 | Identity, Ethnicity, and Place in Modern China | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 88-411 | Rise of the Asian Economies | 9 |

Europe

| | | |
|--------|---|---|
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-268 | World War I: The Twentieth Century's First Catastrophe | 9 |
| 79-270 | Anti-Semitism Then and Now: Perspectives from the Middle Ages to the Present | 9 |
| 79-272 | Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal | 9 |
| 82-320 | Contemporary Society in Germany, Austria and Switzerland | 9 |
| 82-415 | Topics in French and Francophone Studies | 9 |
| 82-441 | Studies in Peninsular Literature and Culture | 9 |

The Middle East

| | | |
|--------|--|---|
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |

The Americas

| | | |
|--------|--|---|
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 82-245 | New Directions in Hispanic Studies | 9 |
| 82-343 | Latin America Language and Culture | 9 |
| 82-451 | Studies in Latin American Literature and Culture | 9 |
| 82-455 | Topics in Hispanic Studies | 9 |
| 82-456 | Topics in Hispanic Studies | 9 |

Electives (2 courses, 15 units minimum)

Students are required to take an additional 15 units (typically two courses) of electives, selected from one or both of the subcategories below. "Theoretical and Topical Core Courses" and "Transnational, Global, and Regional Courses" listed above that are not used to fulfill those requirements may be counted as electives in addition to the courses listed below.

Global Studies offers students the opportunity to gain credit for a 9 unit elective while gaining first-hand experience interning with Pittsburgh-based organizations that work across borders. 79-506 Global Studies Internship is offered every semester and students should register for the course after consulting with the concentration advisor. The concentration advisor will assist students with matching their interests to local organizations and identifying an on-site supervisor available to collaborate in the ongoing and final evaluation of the student's work.

Thematic Courses:

| | | |
|--------|---|------|
| 57-306 | World Music | 9 |
| 70-365 | International Trade and International Law | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 76-449 | Race and Media | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 76-468 | Space and Mobilities | 9 |
| 79-101 | Making History: How to Think About the Past (and Present) | 9 |
| 79-204 | American Environmental History | 9 |
| 79-281 | Introduction to Religion | 9 |
| 79-316 | Photography, the First 100 Years, 1839-1939 | 9 |
| 79-324 | #MeToo: Naming and Resisting Gender Violence | 6 |
| 79-330 | Medicine and Society: Health, Healers, and Hospitals | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 82-215 | Arab Culture Through Dialogues, Film, and Literature | 9 |
| 82-541 | Special Topics in Hispanic Studies | Var. |
| 84-275 | Comparative Politics | 9 |
| 84-310 | International Political Economy | 9 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |

Nation-based Courses:

| | | |
|--------|---|------|
| 79-216 | Genghis Khan and the Mongol Empire | 3 |
| 79-256 | Sex, Guns, Rock, and Skinheads: Youth Rebellion in Europe, 1960-1990 | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-269 | Russian History: From Socialism to Capitalism | 9 |
| 79-309 | The Chinese Revolution Through Film (1949-2000) | 9 |
| 79-319 | India Through Film | 6 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-322 | Stalin and the Great Terror | 9 |
| 79-326 | Shall We Dance? Culture, Politics, and Movement in the 20th Century | 6 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 82-253 | Korean Culture Through Film | 9 |
| 82-254 | World of Korea, Then and Now | 9 |
| 82-273 | Introduction to Japanese Language and Culture | 9 |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 82-294 | 19th Century Russian Masterpieces | 9 |
| 82-295 | 20th Century Russian Masterpieces | Var. |
| 82-303 | French & Francophone Cultures | 9 |
| 82-305 | French in its Social Contexts | 9 |
| 82-333 | Chinese Language and Culture | Var. |
| 82-342 | Spain: Language and Culture | 9 |
| 82-344 | U.S. Latinos: Language and Culture | 9 |
| 82-361 | Italian Language and Culture I | 9 |
| 82-420 | The Crucible of Modernity: Vienna 1900 | 9 |
| 82-425 | Topics in German Literature and Culture | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 82-428 | History of German Film | 9 |
| 82-433 | Topics in Contemporary Culture of China | 9 |
| 82-434 | Studies in Chinese Traditions | 9 |

| | | |
|--------|---|---|
| 82-440 | Studies in Chinese Literature & Culture | 9 |
| 82-473 | Topics in Japanese Studies | 9 |

Hispanic Studies Concentration

(81 units minimum)

A BHA concentration in Hispanic Studies promotes not just language proficiency but also an understanding of its varied cultures. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in Spanish. This is equivalent to the completion of four courses (two at the 100-level and two at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in Hispanic Studies (3 courses, 27 units)

Complete two courses.

| | | |
|--------|------------------------------------|---|
| 82-342 | Spain: Language and Culture | 9 |
| 82-343 | Latin America Language and Culture | 9 |
| 82-344 | U.S. Latinos: Language and Culture | 9 |

Complete required course.

| | | |
|--------|--|---|
| 82-345 | Introduction to Hispanic Literary and Cultural Studies | 9 |
|--------|--|---|

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|---|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in Hispanic Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

Hispanic Studies and Interdisciplinary Electives (5 courses, 45 units)

Complete five courses from Hispanic Studies Electives or four courses from Hispanic Studies Electives and one course from Interdisciplinary Electives in consultation with the concentration advisor.

Hispanic Studies Electives:

| | | |
|------------|--|------|
| 82-441 | Studies in Peninsular Literature and Culture * | 9 |
| 82-443 | Spanish Reading and Translation Workshop | 9 |
| 82-444 | The Structure of Spanish | 6 |
| 82-451 | Studies in Latin American Literature and Culture | 9 |
| 82-455/456 | Topics in Hispanic Studies * | 9 |
| 82-506 | Hispanic Studies Internship * | Var. |
| 82-541/542 | Special Topics in Hispanic Studies * | Var. |

* Students may repeat these courses with new topics.

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and the concentration advisor for the most up to date interdisciplinary electives appropriate for the Hispanic Studies curriculum. Courses may be suggested to the concentration advisor

for approval as a substitute. Note that not all courses are offered each semester.

History

| | | |
|--------|---|---|
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-224 | Mayan America | 9 |
| 79-237 | Comparative Slavery | 9 |
| 79-276 | Beyond the Border | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |

Modern Languages

| | | |
|--------|---|---|
| 82-245 | New Directions in Hispanic Studies | 9 |
| 82-247 | US Latinos Literature | 9 |
| 82-249 | Hispanic Language & Cultures for the Professions | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-281 | Contextual Thinking | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-299 | Equity & Justice in Modern Languages | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Philosophy

| | | |
|--------|--|---|
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-285 | Natural Language Syntax | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-380 | Philosophy of Language | 9 |
| 80-381 | Meaning in Language | 9 |

Psychology

| | | |
|--------|--------------------------|---|
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

Humanities Analytics Concentration

(81 units minimum)

The human experience that is traditionally at the core of a humanities education is being dramatically transformed by the emergence of big data, digital platforms, computational thinking, and digital connectivity. Spurred by such developments, the concentration in Humanities Analytics (HumAn), offered by the Department of English, trains students in the processes involved in analyzing, digitizing, quantifying and visualizing different types of humanities and cultural phenomena, including printed books, manuscripts, historical records, art, music and film. The HumAn concentration trains students to work with cultural objects (like texts, film, historical records, etc.) but also to turn words and images into data; to move from one cultural object (like a Victorian novel, for instance) to a corpus consisting of tens of thousands of other novels published in the same period, and to combine close reading with distant reading (aggregating and analyzing massive amounts of data) for maximum insight and accuracy.

Students will develop a broad technical understanding of state-of-the-art computer-assisted methods for humanistic study, such as: social network analysis, text analysis and data mining, topic modeling, classification techniques and visualization. Students will also investigate the histories and historical contexts of such methods, learning to consider their applicability in specific domains. Finally, students will learn to turn a critical eye on the corpora and infrastructures that increasingly underpin humanistic research.

Required Courses (5 courses, 45 units)

| | | |
|--------|----------------------------------|---|
| 76-275 | Introduction to Critical Writing | 9 |
| 76-380 | Methods in Humanities Analytics | 9 |

Three core courses from the following list:

| | | |
|--------|---|---|
| 76-314 | Data Stories | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-429 | Introduction to Digital Humanities | 9 |
| 88-275 | Bubbles: Data Science for Human Minds | 9 |
| 88-300 | Programming and Data Analysis for Social Scientists | 9 |

Electives (4 courses, 36 units minimum)

Choose four courses from the following categories. One course must come from List A, two from List B, and the fourth in consultation with your Humanities Analytics advisor.

List A: One elective course relevant to digital and analytics methods (at least 9 units):

| | | |
|---------------|---|----|
| 05-391 | Designing Human Centered Software | 12 |
| 05-434/11-344 | Machine Learning in Practice | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-441/741 | Machine Learning for Text and Graph-based Mining (Course is very mathematical, and is therefore appropriate only to students with such a preparation.) | 9 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-110 | Principles of Computing | 10 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 16-223 | IDEATe Portal: Creative Kinetic Systems | 10 |
| 16-385 | Computer Vision | 12 |
| 17-340 | Green Computing | 9 |
| 17-450 | Crafting Software | 12 |
| 17-562 | Law of Computer Technology | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 36-202 | Methods for Statistics & Data Science | 9 |
| 36-204 | Discovering the Data Universe | 3 |
| 36-226 | Introduction to Statistical Inference | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-350 | Statistical Computing | 9 |
| 36-462 | Special Topics: Methods of Statistical Learning | 9 |
| 48-095 | Spatial Concepts for Non-Architecture Majors | 10 |
| 48-120 | Digital Media I | 6 |
| 51-229 | Digital Photographic Imaging | 9 |
| 53-451 | Research Issues in Game Development: Designing for XR | 12 |
| 60/62-142 | Digital Photography I | 10 |
| 62-150 | IDEATe Portal: Introduction to Media Synthesis and Analysis | 10 |

List B: Two elective courses relevant to broad humanities expertise (at least 18 units):

| | | |
|--------|--|---|
| 76-210 | Banned Books | 9 |
| 76-245 | Shakespeare: Tragedies & Histories | 9 |
| 76-247 | Shakespeare: Comedies and Romances | 9 |
| 76-325 | Intertextuality | 9 |
| 76-339 | Topics in Film and Media | 9 |
| 76-373 | Argument | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 79-175 | Moneyball Nation: Data in American Life | 9 |
| 79-200 | Introduction to Historical Research & Writing | 9 |
| 79-234 | Technology and Society | 9 |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-480 | Translation Technologies | 9 |

Note: Additional courses not on List A or List B may also be approved as electives; new courses are added every semester so please speak with Humanities Analytics advisor.

Information Systems Concentration

(107 units minimum)

Did you enjoy computer science or more technical courses in high school, but are mostly interested in the practical and social applications of

technology? Do you have a passion for business and want to use advanced technology to change how companies work? Do you want to learn how data and technology can be harnessed for social good?

The BHA concentration in Information Systems combines aspects of computer science, information technology, and business management to provide you with an uncommonly well-rounded portfolio. You will be uniquely positioned for an impactful career in an increasingly digitized and connected world and able to adapt to rapid evolution across industries.

In addition to building a solid foundation in computing, communications, and software development, you will also study social sciences and organizational theory to develop "big picture" critical thinking and understand the human impacts of technological change. This blend prepares you to take a leading role in our digital future.

Students must earn a final grade of "C" or better for these courses to count toward the concentration.

Technical Core (3 courses, 31 units minimum)

Information Systems requires completion of prerequisite courses in mathematics and computer science. All prerequisites must be successfully completed prior to the start of fall semester, junior year. Two Technical Core courses may double-count in the BHA General Education Math, Science, and Computation category.

| | | |
|-----------|--|----|
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 15-121 | Introduction to Data Structures | 10 |
| or 15-122 | Principles of Imperative Computation | |

Choose one:

| | | |
|--------|------------------------------------|----|
| 21-112 | Calculus II | 10 |
| 21-120 | Differential and Integral Calculus | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-240 | Matrix Algebra with Applications | 10 |
| 80-210 | Logic and Proofs | 9 |

Information Systems Professional Core (8 courses, 76 units)

| | | |
|-----------|--|----|
| 67-200 | Information Systems Research Colloquium -Fall | 1 |
| 67-250 | The Information Systems Milieux -Spring | 9 |
| 67-262 | Database Design and Development -Fall | 9 |
| 67-272 | Application Design and Development -Spring | 12 |
| 67-373 | Information Systems Consulting Project -Spring | 12 |
| 05-391 | Designing Human Centered Software | 12 |
| or 05-410 | User-Centered Research and Evaluation | |
| or 05-452 | Service Design | |
| 17-313 | Foundations of Software Engineering | 12 |
| 95-422 | Managing Digital Transformation | 9 |

International Relations & Political Science Concentration

(81 units minimum)

Offered through the Carnegie Mellon Institute for Security and Technology (CMIST), the International Relations and Political Science (IRPS) BHA concentration is for students who want to learn how to think systematically and develop foundational knowledge about international and domestic politics. It is an interdisciplinary major that is rooted firmly in political science and draws on strengths and insights from decision science, economics, history, modern languages, and other fields. IRPS students wrestle with a wide range of issues including the future of democracy, the relationship between technology and politics, the drivers of war and peace, domestic politics across countries, and the formulation of effective foreign policies. IRPS graduates embark on a variety of careers in government, law, public policy, intelligence, national defense, consulting, international development, and more.

Core disciplinary courses for the IRPS major establish a strong foundation in the study of political science and enable students to better understand the workings of political institutions, political behavior across countries, the decision-making of political leaders, the making national and international policy, and prevailing challenges to the international system, among other topics.

Core methodology courses train IRPS students in the social science tools and communications skills needed to analyze and write persuasively about international relations and politics. Students pursuing an IRPS major learn to use a wide range of analytic tools including statistics and data science, qualitative analysis, game theory, and behavioral decision-making models as they study politics and strategy. Students also learn how to effectively communicate their analyses to affect public policy.

A rich set of electives allows students to investigate issues in security and technology, grand strategy and national security, cybersecurity and international conflict, military strategy and doctrine, the politics of key regions of the world, international political economy and economic policy, representation and voting rights, climate change and development, repression and human rights, international law and diplomacy, political psychology and public opinion, and social change and revolution.

Recognizing the influence of language and culture on politics, students are required to complete the intermediate (200) level, or its equivalent, in a modern language other than English. Advanced-level study is strongly encouraged.

Prerequisite

| | | |
|-----------|----------------------------------|---|
| 84-110 | Foundations of Political Economy | 9 |
| or 73-102 | Principles of Microeconomics | |
| or 73-103 | Principles of Macroeconomics | |

Core Courses (7 courses, 60 units)

| | | |
|-----------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
| 84-226 | International Relations | 9 |
| 84-250 | Writing for Political Science and Policy | 9 |
| 84-266 | Research Design for Political Science | 9 |
| 84-267 | Data Science for Political Science | 9 |
| or 36-202 | Methods for Statistics & Data Science | |
| 84-275 | Comparative Politics | 9 |
| 84-450 | Policy Seminar | 6 |

Language Requirement

BHA IRPS students are required to complete the intermediate (200) level or the equivalent in a modern language other than English. The language requirement may be satisfied by the BHA General Education Modern Languages requirement if the 200-level is reached. Advanced level study is strongly encouraged.

Electives (3 courses, 21 units minimum)

International Relations and Political Science BHA students must take 21 units (three courses) from the elective lists below. Two courses (18 units) must be taken from the Carnegie Mellon Institute for Security and Technology (CMIST) and have an 84-number.

CMIST Electives

| | | |
|--------|---|---|
| 84-200 | Security War Game Simulation | 6 |
| 84-252 | Briefing in the Policy World | 6 |
| 84-303 | International Human Rights | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-306 | Latin American Politics | 9 |
| 84-307 | Economic and Political History of Contemporary China | 9 |
| 84-310 | International Political Economy | 9 |
| 84-312 | Terrorism in Sub-Saharan Africa | 6 |
| 84-315 | Political Economy of International Migration | 9 |
| 84-316 | Political Economy of Transatlantic Partnership | 9 |
| 84-317 | Defense Resourcing: From Strategy to Execution | 6 |
| 84-318 | Politics of Developing Nations | 9 |
| 84-319 | Civil-Military Relations | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-323 | War and Peace in the Contemporary Middle East | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-327 | Repression and Control in Dictatorships | 9 |
| 84-328 | Military Strategy and Doctrine | 9 |
| 84-329 | Asian Strategies | 6 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-365 | The Politics of Fake News and Misinformation | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-372 | Space and National Security | 9 |
| 84-373 | Emerging Technologies and International Law | 9 |
| 84-374 | Technology, Weapons, and International Conflict | 9 |

| | | |
|--------|---|------|
| 84-380 | US Grand Strategy | 9 |
| 84-383 | Cyber Policy as National Policy | 6 |
| 84-386 | The Privatization of Force | 9 |
| 84-387 | Remote Systems and the Cyber Domain in Conflict | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-389 | Terrorism and Insurgency | 9 |
| 84-390 | Social Media, Technology, and Conflict | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-405 | The Future of Warfare | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |
| 84-440 | Collaborative Research in Political Science | Var. |

Additional Electives

| | | |
|--------|---|----|
| 19-452 | EPP Projects II | 12 |
| 70-342 | Managing Across Cultures | 9 |
| 70-365 | International Trade and International Law | 9 |
| 70-430 | International Management | 9 |
| 73-332 | Political Economy | 9 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-257 | Germany and the Second World War | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-264 | Tibet and China: History and Propaganda | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-301 | History of Surveillance: From the Plantation to Data Capitalism | 6 |
| 79-302 | Killer Robots: The Ethics, Law, and Politics of Lethal Autonomous Weapons Systems | 9 |
| 79-313 | "Unwanted": Refugees, Asylum Seekers, and Patterns of Global Migration | 6 |
| 79-314 | How Do We Remember? The Politics and Cultures of Memory | 9 |
| 79-318 | Sustainable Social Change: History and Practice | 9 |
| 79-320 | Women, Politics, and Protest | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-385 | Out of Africa: The Making of the African Diaspora | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-321 | Causation, Law, and Social Policy | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |
| 82-3xx | or 4xx Advanced Level Modern Language Course | |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics in Law: The Bill of Rights | 9 |
| 88-411 | Rise of the Asian Economies | 9 |

Japanese Studies Concentration

(81 units minimum)

A BHA concentration in Japanese Studies promotes not just language proficiency but also an understanding of Japanese culture. Students who

arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Low-intermediate level proficiency in Japanese. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, a Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in Japanese Studies (4 courses, 39 units)

| | | |
|--------|--|----|
| 82-272 | Intermediate Japanese II * | 12 |
| 82-273 | Introduction to Japanese Language and Culture | 9 |
| 82-371 | Changes in Japan 1: Food and Work Cultures | 9 |
| 82-372 | Advanced Japanese II -Changes in Japan II: Lifestyle/Religion and Gender | 9 |

* Students who place out of 82-272 Intermediate Japanese II must take 12 units chosen from the Japanese Studies and Interdisciplinary Electives category below.

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|---|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning or acquisition of language and culture from the listings in Japanese Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

Japanese Studies and Interdisciplinary Electives (4 courses, 33 units minimum)

Complete three courses from Japanese Studies Electives and one course from Interdisciplinary Electives or two courses from Japanese Studies Electives and two courses from Interdisciplinary Electives in consultation with the concentration advisor. With permission of the concentration advisor, students are encouraged to complete at least one Japanese history course that qualifies for Japanese Studies and Interdisciplinary Electives at the University of Pittsburgh, one in Japan when they study abroad or in a summer program at any other university.

Japanese Studies Electives

| | | |
|------------|---|------|
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-473/474 | Topics in Japanese Studies * | 9 |
| 82-505 | Modern Languages Undergraduate Internship | Var. |
| 82-571/572 | Special Topics in Japanese Studies * | Var. |

* Students may repeat these courses with new topics.

Interdisciplinary Electives

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and concentration advisor for the most up to date interdisciplinary electives appropriate for the Japanese Studies curriculum. Courses may be suggested to the concentration advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|---------|------------------------------|---|
| English | | |
| 76-239 | Introduction to Film Studies | 9 |

| | | |
|---------|---|---|
| History | | |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-275 | Introduction to Global Studies | 9 |

Institute for Politics and Strategy (Choose in consultation with the concentration advisor.)

| | | |
|--------|--|---|
| 84-226 | International Relations | 9 |
| 84-310 | International Political Economy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-369 | Decision Science for International Relations | 9 |
| 84-370 | Nuclear Security & Arms Control | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-388 | Concepts of War and Cyber War | 6 |
| 84-405 | The Future of Warfare | 9 |

Modern Languages

| | | |
|--------|---|------|
| 82-270 | Technology in Japanese Culture and Society | 9 |
| 82-275 | Queer Representations in Contemporary Literature and Culture from Japan | Var. |
| 82-278 | Japanese Film and Literature: The Art of Storytelling | 9 |
| 82-279 | Anime - Visual Interplay between Japan and the World | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-373 | Structure of the Japanese Language | 9 |
| 82-374 | Issues in Japanese Technology & Society | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Philosophy

| | | |
|--------|--------------------|---|
| 80-180 | Nature of Language | 9 |
|--------|--------------------|---|

Psychology

| | | |
|--------|--------------------------|---|
| 85-375 | Crosscultural Psychology | 9 |
|--------|--------------------------|---|

Linguistics Concentration

(81 units minimum)

The BHA concentration in Linguistics combines courses from the departments of English, Modern Languages, Philosophy and Psychology and the Language Technologies Institute. Linguistics is the study of human language, and it encompasses a broad spectrum of research questions, approaches and methodologies. Some linguists are concerned with the cognitive aspects of language learning, production and comprehension; some are concerned with language as a social and cultural phenomenon; others engage in the analysis of linguistic form and meaning, some from a functional and others from a formal perspective. There are also computational approaches to linguistics with both applied and theoretical goals.

Introductory Course (1 course, 9 units)

| | | |
|--------|--------------------|---|
| 80-180 | Nature of Language | 9 |
|--------|--------------------|---|

Linguistics Core (2 courses, 18 units)

Take one course each in two of the following three areas.

Sounds:

| | | |
|--------|---------------------------|---|
| 80-282 | Phonetics and Phonology I | 9 |
|--------|---------------------------|---|

Structure:

| | | |
|--------|-------------------------|---|
| 80-280 | Linguistic Analysis | 9 |
| 80-285 | Natural Language Syntax | 9 |

Meaning:

| | | |
|--------|---------------------|---|
| 80-381 | Meaning in Language | 9 |
| 80-383 | Language in Use | 9 |

Extended Core (3 courses, 27 units)

Choose three courses from Extended Core or additional courses from the Linguistics Core above.

| | | |
|--------|---|---|
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-488 | Acoustics of Human Speech: Theory, Data, and Analysis | 9 |

Elective Courses (3 courses, 27 units)

Take three additional electives. These can be additional courses from the Core or Extended Core courses listed above, the electives list below, or any other course which must be approved by the concentration advisor as a linguistics elective. Listed below are the additional electives taught on a regular basis. Additional appropriate courses are offered irregularly or on a one-off basis. The concentration advisor will provide students with a list of possible electives each semester, and will assist students in selecting electives that are consistent with their goals and interests. A list of these courses must be filed in the BXA office.

Philosophy:

| | | |
|--------|------------------------|---|
| 80-380 | Philosophy of Language | 9 |
| 80-484 | Language and Thought | 9 |

English:

| | | |
|--------|---|---|
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-325 | Intertextuality | 9 |
| 76-385 | Introduction to Discourse Analysis | 9 |
| 76-386 | Language & Culture | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |

Modern Languages:

| | | |
|--------|--|---|
| 82-239 | Crazy Linguistically Rich Asian Languages | 9 |
| 82-305 | French in its Social Contexts | 9 |
| 82-334 | Structure of Chinese | 9 |
| 82-373 | Structure of the Japanese Language | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-585 | Topics in Second Language Acquisition | 9 |
| 82-304 | French & Francophone Sociolinguistics | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |

Psychology:

| | | |
|--------|-----------------------------|---|
| 85-354 | Infant Language Development | 9 |
| 85-421 | Language and Thought | 9 |

Language Technologies Institute:

| | | |
|--------|--|----|
| 11-411 | Natural Language Processing | 12 |
| 11-423 | ConLanging: Lrng. Ling. & Lang Tech via Constru Artif. Lang. | 12 |
| 11-492 | Speech Processing | 12 |
| 11-422 | Grammar Formalisims | 12 |

Statistics and Data Science:

| | | |
|--------|-------------------------------|---|
| 36-468 | Special Topics: Text Analysis | 9 |
|--------|-------------------------------|---|

Literature & Culture Concentration

(81 units minimum)

The BHA concentration in Literature & Culture teaches students how to read, interpret and write persuasively about novels, poems, plays and other imaginative works across a variety of genres and media forms. Along

with teaching students the analytical skills and methodological tools to interpret these works, this major teaches the importance of understanding imaginative works within their cultural and historical contexts. In addition, the concentration is designed to train students in strong professional and academic skills like critical thinking, inductive reasoning and persuasive argumentation that are applicable to other fields of study and a variety of career paths.

Prerequisite Course

Choose one course:

| | | |
|--------|---|---|
| 76-260 | Introduction to Writing Fiction | 9 |
| 76-261 | Introduction to Writing Creative Nonfiction | 9 |
| 76-265 | Introduction to Writing Poetry | 9 |
| 76-269 | Introduction to Screenwriting | 9 |

Required Introductory Courses (2 courses, 18 units)

| | | |
|-----------|------------------------------------|---|
| 76-245 | Shakespeare: Tragedies & Histories | 9 |
| or 76-247 | Shakespeare: Comedies and Romances | |
| 76-275 | Introduction to Critical Writing | 9 |

200-Level Literature & Culture Course (1 course, 9 units)

Course options include but are not limited to the following:

| | | |
|--------|--|---|
| 76-203 | Literature & Culture in the 18th Century | 9 |
| 76-207 | Special Topics in Literature & Culture | 9 |
| 76-210 | Banned Books | 9 |
| 76-217 | Literature & Culture of the 20th and 21st Century | 9 |
| 76-221 | Books You Should Have Read By Now | 9 |
| 76-230 | Literature & Culture in the 19th Century | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-233 | Literature and Culture in the Renaissance | 9 |
| 76-245 | Shakespeare: Tragedies & Histories (if not taken as Required Introductory Course) | 9 |
| 76-247 | Shakespeare: Comedies and Romances (if not taken as Required Introductory Course) | 9 |

300-Level Course (1 course, 9 units)

Course options include but are not limited to the following:

| | | |
|--------|--|---|
| 76-310 | Advanced Studies in Film and Media | 9 |
| 76-314 | Data Stories | 9 |
| 76-316 | Topics in Literature: Watching HBO's The Watchmen | 9 |
| 76-317 | Contemporary American Fiction | 9 |
| 76-329 | Performing Race in Early Modernity | 9 |
| 76-337 | Intersectional Feminism (if not taken for the Theory Course requirement) | 9 |
| 76-339 | Topics in Film and Media | 9 |
| 76-341 | Race & Gender in the Age of Jane Austen | 9 |
| 76-342 | Love: A Cultural History | 9 |
| 76-343 | Rise of the American Novel | 9 |
| 76-350 | Critical Theories about Literature (if not taken for the Theory Course requirement) | 9 |
| 76-367 | Fact Into Film: Translating History into Cinema | 9 |
| 76-376 | History of Critical Ideas (if not taken for the Theory Course requirement) | 9 |
| 76-388 | Coding for Humanists | 9 |

400-Level Course (1 course, 9 units)

Course options include but are not limited to the following:

| | | |
|--------|--|---|
| 76-407 | Topics in Literary & Cultural Studies | 9 |
| 76-408 | Culture and Globalization | 9 |
| 76-410 | The Long Eighteenth Century | 9 |
| 76-423 | Transnational Feminisms | 9 |
| 76-429 | Introduction to Digital Humanities | 9 |
| 76-439 | Seminar in Film and Media Studies | 9 |
| 76-440 | Postcolonial Theory: Diaspora and Transnationalism | 9 |
| 76-446 | Revenge Tragedy | 9 |
| 76-448 | Shakespeare on Film | 9 |
| 76-452 | Generations and Culture | 9 |
| 76-467 | Crime Fiction and Film | 9 |

Theory Course (1 course, 9 units)

Course options include but are not limited to the following:

| | | |
|--------|--|---|
| 76-337 | Intersectional Feminism (if not taken as a 300-Level Course) | 9 |
| 76-350 | Critical Theories about Literature (if not taken as a 300-Level Course) | 9 |
| 76-376 | History of Critical Ideas (if not taken for the Theory Course requirement) | 9 |

Rhetoric Course (1 course, 9 units)

Course options include but are not limited to the following:

| | | |
|--------|---|---|
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-373 | Argument | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-418 | Rhetoric and the Body | 9 |
| 76-457 | Rhetorical Invention | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-484 | Discourse Analysis | 9 |
| 76-491 | Rhetorical Analysis | 9 |
| 76-492 | Rhetoric of Public Policy | 9 |
| 76-496 | Research Methods in Rhetoric & Writing Studies (permission required from instructor) | 9 |

English Elective Courses (2 courses, 18 units)

Complete two additional courses from the English Department's offerings. One course must be at the 300-level, and one must be at the 400-level. Electives may include any courses offered by the English Department from any specialization area, with the exception of creative writing workshops.

Logic & Computation Concentration

(81 units minimum)

Students in the program take a common core of courses in logic, methodology, and computer science, together with an associated seminar in their senior year. The individual focus is achieved by selecting a sequence of four advanced and closely related courses. It is in this area of focus (or specialization) that students write their senior thesis under the supervision of a faculty member.

The resulting education in logic, analytic philosophy, mathematics, statistics and computer science enables students to pursue professional careers or graduate study. The analytic and communication skills developed in the major support a wide range of career choices, including those among the fields of technology, business and law. Fields of graduate study for which students are well prepared include, for example, computer science, cognitive science, philosophy, logic and linguistics.

Prerequisites

| | | |
|--------|---|----|
| 80-211 | Logic and Mathematical Inquiry (Recommended prior to 21-127) | 9 |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |
| 21-127 | Concepts of Mathematics | 12 |

Logic & Computation Core (5 courses, 51 units)

| | | |
|--------|--------------------------------------|----|
| 15-122 | Principles of Imperative Computation | 12 |
| 15-150 | Principles of Functional Programming | 12 |
| 80-150 | Nature of Reason | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |

Logic & Computation Electives (3-4 courses, 30 units minimum)

Bearing in mind prerequisites, Logic & Computation students must complete at least three advanced courses in areas that use logical and computational tools, such as philosophy, computer science, linguistics, mathematical logic, psychology or statistics. The sequence of courses, mostly at the 300-level, must be selected in consultation with the concentration advisor.

Philosophy Concentration

(81 units minimum)

The BHA Concentration in Philosophy provides students with a broad humanities education and sharpens their analytical skills. We encourage, but do not require, students to choose a thematic concentration through their electives. Sample curricula emphasizing Pre-Law, Metaphysics and Epistemology, Ethics and Social Philosophy, and Philosophy of Mind are suggested below. However, alternative emphases can be proposed and approved by the concentration advisor.

In any of the areas listed, substitutions of courses that cohere with a student's interest may be allowed with approval from the concentration advisor.

Introduction to Philosophy (1 course, 9 units)

| | | |
|--------|----------------------------|---|
| 80-100 | Introduction to Philosophy | 9 |
|--------|----------------------------|---|

Area 1: Values and Normative Theory (1 course, 9 units)

| | | |
|--------|---|---|
| 80-130 | Introduction to Ethics | 9 |
| 80-234 | Race, Gender, and Justice | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-136 | Social Structure, Public Policy & Ethics | 9 |
| 80-244 | Environmental Ethics | 9 |
| 80-245 | Medical Ethics | 9 |
| 80-246 | Moral Psychology | 9 |
| 80-249 | AI, Society, and Humanity | 9 |
| 80-330 | Ethical Theory | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 80-336 | Philosophy of Law | 9 |
| 80-348 | Health, Human Rights, and International Development | 9 |
| 80-447 | Global Justice | 9 |

Area 2: Philosophy of Mind/Language/Metaphysics (1 course, 9 units)

| | | |
|--------|--|---|
| 80-180 | Nature of Language | 9 |
| 80-270 | Problems of Mind and Body: Meaning and Doing | 9 |
| 80-271 | Mind and Body: The Objective and the Subjective | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-282 | Phonetics and Phonology I | 9 |
| 80-283 | It Matters How You Say It | 9 |
| 80-284 | Invented Languages | 9 |
| 80-285 | Natural Language Syntax | 9 |
| 80-286 | Words and Word Formation: Introduction to Morphology | 9 |
| 80-287 | Language Variation and Change | 9 |
| 80-288 | Intonation: Transcription and Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| 80-381 | Meaning in Language | 9 |
| 80-382 | Phonetics and Phonology II | 9 |
| 80-383 | Language in Use | 9 |
| 80-384 | Linguistics of Turkic Languages | 9 |
| 80-385 | Linguistics of Germanic Languages | 9 |
| 80-388 | Linguistic Typology: Diversity and Universals | 9 |
| 80-580 | Seminar on the Philosophy of Language | 9 |

Area 3: Logic/Philosophy of Mathematics (1 course, 9 units)

| | | |
|--------|-----------------------------------|---|
| 80-210 | Logic and Proofs | 9 |
| 80-211 | Logic and Mathematical Inquiry | 9 |
| 80-212 | Arguments and Logical Analysis | 9 |
| 80-310 | Formal Logic | 9 |
| 80-311 | Undecidability and Incompleteness | 9 |
| 80-312 | Mathematical Revolutions | 9 |
| 80-315 | Modal Logic | 9 |
| 80-411 | Proof Theory | 9 |
| 80-413 | Category Theory | 9 |
| 80-419 | Interactive Theorem Proving | 9 |
| 80-514 | Categorical Logic | 9 |
| 80-518 | Seminar on Topics in Logic | 9 |

Area 4: Epistemology/Methodology (1 course, 9 units)

| | | |
|--------|--------------------------------|---|
| 80-150 | Nature of Reason | 9 |
| 80-201 | Knowledge and Justified Belief | 9 |
| 80-208 | Critical Thinking | 9 |

| | | |
|--------|---|---|
| 80-220 | Philosophy of Science | 9 |
| 80-221 | Philosophy of Social Science | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-305 | Game Theory | 9 |
| 80-306 | Decision Theory | 9 |
| 80-324 | Philosophy of Economics | 9 |
| 80-326 | Epistemology of Machine Learning | 9 |
| 80-516 | Causality and Machine Learning | 9 |
| 80-521 | Seminar on Formal Epistemology: Belief and Evidence | 9 |
| 80-325 | Foundations of Causation and Machine Learning | 9 |

Area 5: History of Philosophy (1 course, 9 units)

| | | |
|--------|--------------------------------------|---|
| 80-150 | Nature of Reason | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-252 | Kant | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-256 | Modern Moral Philosophy | 9 |
| 80-257 | Nietzsche | 9 |
| 80-261 | Experience, Reason, and Truth | 9 |
| 80-358 | Hume | 9 |

Area 6: Electives (3 courses, 27 units)

Three other philosophy courses, or appropriate courses from other departments, with the permission of the concentration advisor.

Policy & Management Concentration

(87 units minimum)

The Policy & Management concentration prepares students for key decision-making and management roles in government, non-profit organizations and business. The concentration emphasizes analytical approaches to decision making, practical management skills and empirical techniques necessary for graduates to excel in the public and private sectors. The multidisciplinary curriculum merges frontier knowledge on the ideals of decision making, policy and data analysis, as well as the realities of individual behavior within various institutional settings that must be confronted if high-quality outcomes are to be attained.

The Policy & Management concentration provides an excellent combination of theoretical and practical skills for students who intend to seek managerial positions. Because of its strong analytic orientation, it is also an excellent concentration for those who intend to go on to professional school programs in law, business or public policy. It is also an appropriate choice for students pursuing graduate degrees in economics, political science or decision science.

Policy Core (2 courses, 18 units)

The Policy Core gives students applied economic training and policy analysis experience. Students will gain an analytical understanding of some of the biggest domestic and global economic policy challenges, and gain an appreciation of the economic analysis of complex decisions, as well as the trade-off between economic and political-based decision making.

| | | |
|--------|---------------------------------------|---|
| 73-102 | Principles of Microeconomics | 9 |
| 88-221 | Markets, Democracy, and Public Policy | 9 |

Management Core (3 courses, 30 units)

The Management Core focuses on real-world applications of decision making. Students will develop an understanding of effective negotiation strategies and tactics, and identify the barriers and the psychological factors that may prevent decision-makers from reaching wise agreements. The courses provide systematic methods for dealing with the complexities that make decisions difficult, ranging from incorporating issues of risk and uncertainty in decision making to dealing with choices that have mutually conflicting objectives. For example, a business or government agency may need to decide on a policy for mitigating the uncertain impacts of air pollution while simultaneously trying to minimize the costs of such a policy on manufacturing. A firm might want to consider the uncertain reductions in security dangers from alternative policies to protect against terrorism.

| | | |
|-----------|---|----|
| 88-150 | Managing Decisions | 9 |
| or 88-255 | Strategic Decision Making | |
| 88-223 | Decision Analysis | 12 |
| 88-418 | Negotiation: Strategies and Behavioral Insights | 9 |
| or 88-419 | International Negotiation | |

Empirical Core (3 courses, 27 units)

The Empirical Core focuses on key methods for collecting and analyzing data that are needed to make informed decisions. Students learn to use interviews, surveys, experiments and econometric methods to enhance their ability to test existing, and design new policies. Students will create statistical models to address questions asked in conceptual, computational and data-driven investigations.

| | | |
|-----------|---------------------------------------|---|
| 36-202 | Methods for Statistics & Data Science | 9 |
| 88-251 | Empirical Research Methods | 9 |
| 88-252 | Cause and Effect | 9 |
| or 88-275 | Bubbles: Data Science for Human Minds | |

Senior Project (1 course, 12 units)

The required Senior Project course gives students hands-on experience in a policy-related area. Students work in teams to apply the research and analytical methods learned in their other courses to a real-world problem.

| | | |
|------------|--------------------------------|----|
| 88-451/452 | Policy Analysis Senior Project | 12 |
|------------|--------------------------------|----|

Politics & Public Policy Concentration

(81 units minimum)

Rooted in the discipline of political science, the concentration in Politics and Public Policy investigates US public policy issues and other matters of domestic politics while providing students hands-on and practical learning experiences. Students pursuing the Politics and Public Policy minor must participate in the Carnegie Mellon University Washington Semester Program (CMU/WSP) (<https://www.cmu.edu/ips/washington-dc-semester-program/>) for one semester during their undergraduate years.

The CMU/WSP, sponsored by the Carnegie Mellon Institute for Security and Technology (CMIST), is a semester-long program in which students live, intern, and take CMU classes in Washington, DC. Undergraduates from any course of study at the university may participate in the program. Students earn 48 units for the Carnegie Mellon University Washington Semester Program, interning about twenty-four hours per week in any sector or field of interest within Washington, DC, while taking classes taught by Carnegie Mellon faculty.

From embassies to nongovernmental organizations, think tanks to advocacy organizations, government agencies to congressional offices, and consulting firms to media outlets, Washington, DC, is the center of US political, international, and public policy activities. Students in the program come into direct contact with policymakers, Congressmen, think tank leaders, and business leaders, and through hands-on experience learn about the most pressing policy issues of the day.

Through this experiential learning program, CMU/WSP participants develop professional and networking skills, explore how coursework connects to the real world, learn to give and receive constructive feedback in the workplace and classroom, and intentionally reflect on their learning and growth. Every CMU/WSP student is paired with a Washington, DC- based alumni mentor to share career advice and tips about life in DC. CMIST also sponsors events and policy-oriented opportunities in Washington for students participating in the program to further enrich their experience and enhance their understanding of how Washington functions as a hub of international and domestic policy decision making.

Foundation Courses (2 courses, 18 units)

Students must complete the following course:

| | | |
|--------|---|---|
| 84-104 | Decision Processes in American Political Institutions | 9 |
|--------|---|---|

Students must complete one of the following courses:

| | | |
|-----------|-------------------------|---|
| 84-275 | Comparative Politics | 9 |
| or 84-226 | International Relations | |

Economics Course (1 course, 9 units)

Students must complete one of the following courses:

| | | |
|-----------|----------------------------------|---|
| 84-110 | Foundations of Political Economy | 9 |
| or 73-102 | Principles of Microeconomics | |
| or 73-103 | Principles of Macroeconomics | |

CMU/WSP Core Seminars (3 courses, 24 units)

Students must take the following courses while participating in the CMU/WSP:

| | | |
|--------|-----------------------------|----|
| 84-360 | CMU/WSP: Internship Seminar | 12 |
| 84-450 | Policy Seminar | 6 |
| 84-451 | Policy Seminar II | 6 |

CMU/WSP Elective Seminars (3 course, 24 units minimum)

Students must take 24 units from the below list of elective seminars offered in the CMU/WSP. Offerings vary by semester:

| | | |
|--------|--|----|
| 84-330 | The Shading of Democracy: The Influence of Race on American Politics | 6 |
| 84-331 | Money, Media, and the Power of Data in Decisionmaking | 6 |
| 84-333 | Power and Levers for Change in Washington, DC | 12 |
| 84-334 | The History and Practice of Economic Statecraft | 6 |
| 84-335 | US China Relations | 6 |
| 84-336 | Implementing Public Policy: From Good Idea To Reality | 12 |
| 84-337 | Biomedical Science Research, Policy, and Governance | 6 |
| 84-339 | Seminar in Public Policy Research | 12 |
| 84-340 | Making Change: How Organized Interests Work in Washington | 12 |
| 84-348 | Advocacy, Policy and Practice | 6 |

American Politics Elective (1 course, 6 units minimum)

Students must take one course from the below list of electives taught in Pittsburgh.

| | | |
|--------|---|---|
| 84-252 | Briefing in the Policy World | 6 |
| 84-304 | In the News: Analysis of Current National Security Priorities | 6 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-352 | Representation and Voting Rights | 9 |
| 84-354 | The American Experiment: Unravelling the US Electoral System | 6 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-393 | Legislative Decision Making: US Congress | 9 |
| 84-402 | Judicial Politics and Behavior | 9 |
| 84-421 | Advanced Topics in American Politics | 9 |

Professional Writing Concentration

(84 units minimum)

Professional Writing combines liberal and professional education with a strong foundation in rhetorical studies. The concentration in Professional Writing has a strong career orientation and is specifically designed to prepare students for successful careers as writers and communications specialists in a range of fields: publishing, government, journalism, the non-profit sector, education, public and media relations, corporate communications, advocacy writing and the arts. The concentration is designed to develop articulate and reflective communications professionals with both the skills needed to enter and negotiate current work contexts (including writing for the web and other digital media) and the analytic and problem-solving skills needed to understand and keep pace with cultural and technological change.

Prerequisite English Elective

Students with a concentration in Professional Writing must complete one prerequisite course from the English Department's offerings, which focuses on the relationships between texts and their cultural and historical contexts. The course must be at or above the 200 level. 76-270 Writing for the Professions, and 76-271 Introduction to Professional and Technical Writing may not count as English electives. Appropriate courses are advertised

every semester in the English department's "What Counts for What" publication.

Foundation Courses (5 courses, 39 units)

| | | |
|--------|--|---|
| 76-26x | Introductory Genre Writing Course (Nonfiction, Fiction, Poetry or Screenwriting) | 9 |
| 76-271 | Introduction to Professional and Technical Writing | 9 |
| 76-300 | Professional Seminar | 3 |
| 76-373 | Argument | 9 |
| 76-390 | Style | 9 |

Rhetoric/Language Studies Course (1 course, 9 units)

Students with a concentration in Professional Writing complete one course from designated Rhetoric courses offered and advertised each semester by the English Department. Rhetoric courses focus on understanding the role of language and language practices in both personal and professional contexts. Courses emphasize the relationships between texts and their contexts and pay particular attention to textual features, meaning, processes of reading and writing, and the ways in which language practices vary over time and across situations and cultures. The courses also equip students with explicit techniques for analyzing, understanding and exploring language practices. The Rhetoric/Language Studies courses may also be taken as part of the concentration requirements for three additional, Advanced Writing/Rhetoric courses and include but are not limited to the following list.

| | | |
|--------|-------------------------------|---|
| 76-325 | Intertextuality | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-360 | Literary Journalism Workshop | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-395 | Science Writing | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-474 | Software Documentation | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-494 | Healthcare Communications | 9 |

Advanced Writing/Rhetoric Courses (3 courses, 27 units minimum)

Students with a concentration in Professional Writing complete three Advanced Writing/Rhetoric courses at the 300- or 400-level at a minimum of 27 units, as some courses are only six units, while others are variable units. Options for these courses include all of the Rhetoric/Language Studies courses listed above plus the writing-focused courses listed below. Additional courses that fulfill these requirements are advertised on a semester-by-semester basis. For help in choosing which of the possible options are most appropriate for various professional goals - journalism, writing for new media, editing and publishing, public relations/corporate communications, or science and technical writing - consult your English Department advisor. All students with a concentration in PW, regardless of their career focus, are encouraged to take 76-391 Document & Information Design and 76-487 Information Architecture & Content Strategy (formerly titled Web Design) to extend their skills in writing for print to include information design for digital media. Both courses focus on the role of the writer in these specializations and provide lab instruction in the relevant software and related computer skills.

Courses include but are not limited to:

| | | |
|--------|--|------|
| 76-301 | Internship | Var. |
| 76-302 | Communication Support Tutoring Practicum | 6 |
| 76-314 | Data Stories | 9 |
| 76-351 | Rhetorical Invention | 9 |
| 76-354 | Watchdog Journalism | 9 |
| 76-360 | Literary Journalism Workshop | 9 |
| 76-372 | News Writing | 9 |
| 76-380 | Methods in Humanities Analytics | 9 |
| 76-388 | Coding for Humanists | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-391 | Document & Information Design | 9 |
| 76-395 | Science Writing | 9 |
| 76-415 | Mediated Power and Propaganda | 9 |
| 76-418 | Rhetoric and the Body | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-457 | Rhetorical Invention | 9 |
| 76-464 | Creative Nonfiction Workshop | 9 |

| | | |
|--------|---|----|
| 76-474 | Software Documentation | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-483 | Research Methods in Technical & Professional Communication | 9 |
| 76-484 | Discourse Analysis | 9 |
| 76-487 | Web Design - Information Architecture & Content Strategy (formerly titled Web Design) | 12 |
| 76-492 | Rhetoric of Public Policy | 9 |
| 76-494 | Healthcare Communications | 9 |
| 76-496 | Research Methods in Rhetoric & Writing Studies (instructor permission required) | 9 |

English Elective (1 course, 9 units minimum)

Students with a concentration in Professional Writing complete one additional course from the English Department's offerings. This course should be one that focuses on the relationships between texts and their cultural and historical contexts. Courses in literature, cultural studies, rhetoric and media studies that meet this requirement are advertised on a semester-by-semester basis. The English Elective may be any course offered by the Department with the exception of 76-270 Writing for the Professions, which is designed for non-majors and overlap with 76-271 Introduction to Professional and Technical Writing.

Psychology Concentration

(81 units minimum)

Psychology is a science that embraces both biological and social sciences. It is a science concerned with establishing principles and laws regarding the ways in which people think, feel, and behave through the scientific study of human behavior. Students with a concentration in Psychology are expected not only to learn about findings already established by psychologists, but also to become proficient in the investigation and analysis of behavior. This includes observing behavior, formulating hypotheses, designing experiments to test these hypotheses, running experiments, performing statistical analyses and writing reports.

Breadth Courses (4 courses, 36 units)

To gain familiarity with the breadth of the field of Psychology, students take 85-102 Introduction to Psychology and three survey courses.

Required Intro Course:

| | | |
|--------|----------------------------|---|
| 85-102 | Introduction to Psychology | 9 |
|--------|----------------------------|---|

Survey Courses:

| | | |
|-----------|--|---|
| 85-104 | Psychopathology | 9 |
| 85-211 | Cognitive Psychology | 9 |
| or 85-213 | Human Information Processing and Artificial Intelligence | |
| 85-219 | Foundations of Brain and Behavior | 9 |
| 85-221 | Principles of Child Development | 9 |
| 85-241 | Social Psychology | 9 |
| 85-251 | Personality | 9 |

Research Methods and Statistics (2 courses, 18 units)

Students complete one course in Research Methods (9 units). The corresponding survey course is a prerequisite for this course.

| | | |
|--------|--|---|
| 85-310 | Research Methods in Cognitive Psychology | 9 |
| 85-314 | Cognitive Neuroscience Research Methods | 9 |
| 85-320 | Research Methods in Developmental Psychology | 9 |
| 85-330 | Analytic Research Methods | 9 |
| 85-340 | Research Methods in Social Psychology | 9 |

The following Statistics course is a prerequisite for all the Research Methods courses. This Statistics course counts toward the Psychology concentration.

| | | |
|-----------|--|---|
| 36-309 | Experimental Design for Behavioral & Social Sciences -Fall | 9 |
| or 85-309 | Statistical Concepts and Methods for Behavioral and Social Science | |

Advanced Courses (3 courses, 27 units)

Complete any three advanced courses or seminars in Psychology numbered higher than 85-349. (excepting 85-480, 85-482, 85-484, 85-506, 85-507, 85-508).

Russian Studies Concentration

(87 units minimum)

A BHA concentration in Russian Studies promotes not just language proficiency but also an understanding of Russian culture. Students who arrive at Carnegie Mellon with previous language study and/or who have high Advanced Placement, an International Baccalaureate, a Cambridge GCE Advanced level or internal placement exam scores will be able to begin taking courses in the concentration earlier in their undergraduate program. In all cases, progress in the concentration will be accelerated by study abroad, which is recommended for all students.

Prerequisites

Intermediate level proficiency in Russian. This is equivalent to the completion of three courses (two at the 100-level and one at the 200-level) or exemption based on Advanced Placement, International Baccalaureate, Cambridge GCE Advanced level or Carnegie Mellon internal placement test scores.

Core Courses in Russian Studies (3 courses, 33 units)

| | | |
|-----------|--|------|
| 82-292 | Intermediate Russian II | 12 |
| 82-294 | 19th Century Russian Masterpieces (12 units) | Var. |
| or 82-295 | 20th Century Russian Masterpieces | |
| 79-265 | Russian History: Game of Thrones | 9 |
| or 79-266 | Russian History and Revolutionary Socialism | |

Core Courses in Modern Languages (1 course, 9 units)

Complete one course.

| | | |
|--------|---|---|
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |

Note: In consultation with the concentration advisor, students may substitute a Modern Languages course elective with one related to language analysis, language learning, or acquisition of language and culture from the listings in Russian Studies or from another department. Examples: 80-180 Nature of Language, 85-421 Language and Thought. In addition, students may choose to take 82-580 Senior Seminar in Modern Languages (9 units). The selected course may not double count in the Electives category.

Russian Studies and Interdisciplinary Electives (5 courses, 45 units minimum)

Complete two courses from Russian Studies Electives or one course from Russian Studies Electives and one course from Interdisciplinary Electives in consultation with the concentration advisor.

Russian Studies Electives:

| | | |
|--------|---|------|
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | Var. |
| 82-297 | Russian and Soviet Science Fiction | Var. |
| 82-390 | Soviet Futures: Revolutionary Design | 9 |
| 82-391 | Advanced Russian I - Berlin, Paris, New York, Harbin | 9 |
| 82-392 | Advanced Russian II: Great Short Works | 9 |
| 82-394 | Russian for Heritage Speakers: Babushka's Russia & Beyond | 9 |
| 82-397 | Radicals, Heretics, Hackers: Russian Outlaws in History, Literature, and Film | Var. |
| 82-599 | Russian Studies Thesis | 9 |

* Students may repeat these courses with new topics.

Interdisciplinary Electives:

This list is compiled from possibilities such as but not limited to the following. Students should consult SIO and the concentration advisor for the most up to date interdisciplinary electives appropriate for the Russian Studies curriculum. Courses may be suggested to the concentration advisor for approval as a substitute. Note that not all courses are offered each semester.

| | | |
|--|---|---|
| English | | |
| 76-239 | Introduction to Film Studies | 9 |
| History | | |
| 79-205 | 20th Century Europe | 9 |
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-322 | Stalin and the Great Terror | 9 |
| Institute for Politics and Strategy (Choose in consultation with the concentration advisor.) | | |
| 84-380 | US Grand Strategy | 9 |
| 84-405 | The Future of Warfare | 9 |
| Modern Languages | | |
| 82-208 | Eastern Europe: Society and Culture | 9 |
| 82-280 | Bilingual & Bicultural Experiences in the US | 9 |
| 82-282 | Interpreting Global Texts & Cultures | 9 |
| 82-283 | Language Diversity & Cultural Identity | 9 |
| 82-284 | Multicultural Pittsburgh: VR Storytelling | 9 |
| 82-285 | Podcasting: Language and Culture Through Storytelling | 9 |
| 82-286 | Cultural Complexities | 9 |
| 82-383 | Second Language Acquisition: Theories and Research | 9 |
| 82-388 | Topics in Second Language Acquisition | 9 |
| 82-480 | Translation Technologies | 9 |
| Philosophy | | |
| 80-180 | Nature of Language | 9 |
| 80-280 | Linguistic Analysis | 9 |
| 80-380 | Philosophy of Language | 9 |
| Psychology | | |
| 85-375 | Crosscultural Psychology | 9 |
| 85-421 | Language and Thought | 9 |

* Students may repeat these courses with new topics.

Social & Political History Concentration

(84 units minimum)

The BHA concentration in Social & Political History focuses on new ways to understand the past and new ways to use what we know, as well as on connections between past and present and on how historical knowledge facilitates understanding of social, cultural and policy change. The History concentration emphasizes empirical methods and conceptual analysis, as well as specific research skills relevant to many types of jobs and further professional training. The History concentration combines a structured sequence of courses, training in research methods, theoretical concepts, and analytical writing skills, plus a considerable array of electives.

The BHA concentration in Social & Political History emphasizes broad-based, cumulative knowledge and interpretive skills in the study of the past. Offerings at the 200- and 300-level are designed to allow maximum flexibility in meeting requirements and maximum choice in focusing on particular themes, places, or eras. Upper-level courses aim to give students majoring in History more time together in smaller classes and more experience working with primary and secondary sources. The senior capstone seminar, Historical Research Seminar, provides training and experience in conducting original research and in interpretive, analytical writing—skills that prepare graduates for professional careers as well as for graduate or law school.

Required History Courses (2 courses, 21 units)

Students must earn a final grade of “C” or better for these courses to count toward the concentration.

| | | |
|--------|--|----|
| 79-200 | Introduction to Historical Research & Writing - Sophomore or Junior year | 9 |
| 79-420 | Historical Research Seminar -Fall, Senior year | 12 |

Required Survey Courses (2 courses, 18 units)

| | | |
|--------|---|---|
| 79-160 | Introduction to the History of Science | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-203 | The Other Europe: The Habsburgs, Communism, & Central/Eastern Europe, 1740-1990 | 9 |
| 79-204 | American Environmental History | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-206 | Crime and Punishment in Early Modern Europe | 9 |

| | | |
|--------|--|---|
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-212 | Jim Crow America | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-225 | West African History in Film | 9 |
| 79-226 | African History: Earliest Times to 1780 | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-248 | U.S. Constitution & the Presidency | 9 |
| 79-249 | 20th Century U.S. History | 9 |
| 79-250 | Voting Rights: An Introduction | 9 |
| 79-260 | Nazi Germany | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |
| 79-269 | Russian History: From Socialism to Capitalism | 9 |
| 79-272 | Coexistence and Conflict: Muslims, Christians and Jews in Spain and Portugal | 9 |
| 79-282 | Europe and the World Since 1800 | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-320 | Women, Politics, and Protest | 9 |

Social & Political History Elective Courses (5 courses, 45 units minimum)

A minimum of 45 additional History units must be approved with the History advisor. Any History courses not fulfilling another major requirement may be chosen as an elective. Any History (79-xxx) class can count as an SPH elective except for 79-198, 79-200, 79-400, 79-420, 79-449, 79-491). See the History Department website (www.cmu.edu/dietrich/history) (<https://www.cmu.edu/dietrich/history/>) or contact the History advisor for the most current elective offerings.

Students may satisfy the elective requirements in SPH with up to 27 units of the following courses offered by other departments in Dietrich College:

| | | |
|--------|---|---|
| 73-476 | American Economic History | 9 |
| 76-230 | Literature & Culture in the 19th Century | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-295 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 76-449 | Race and Media | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-226 | The Nature of Scientific Revolutions | 9 |
| 80-335 | Social and Political Philosophy | 9 |
| 82-208 | Eastern Europe: Society and Culture | 9 |
| 82-245 | New Directions in Hispanic Studies | 9 |
| 82-247 | US Latinos Literature | 9 |
| 82-293 | Russian Cinema: From the Bolshevik Revolution to Putin's Russia | 9 |
| 82-327 | The Emergence of the German Speaking World | 9 |
| 82-420 | The Crucible of Modernity:Vienna 1900 | 9 |
| 82-427 | Nazi and Resistance Culture | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-322 | Nonviolent Conflict and Revolution | 9 |
| 84-324 | The Future of Democracy | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 84-362 | Diplomacy and Statecraft | 9 |
| 84-380 | US Grand Strategy | 9 |
| 84-386 | The Privatization of Force | 9 |
| 84-389 | Terrorism and Insurgency | 9 |

| | | |
|--------|--|---|
| 85-380 | In Search of Mind: The History of Psychology | 9 |
| 88-281 | Topics in Law: 1st Amendment | 9 |
| 88-284 | Topics of Law: The Bill of Rights | 9 |

Statistics Concentration

(81 units minimum)

In the BHA concentration in Statistics, students develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration.

Prerequisites

These courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

| | | |
|-----------|--|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-256 | Multivariate Analysis | 9 |
| or 21-259 | Calculus in Three Dimensions | |
| 21-240 | Matrix Algebra with Applications | 10 |
| or 21-241 | Matrices and Linear Transformations | |
| or 21-242 | Matrix Theory | |
| 15-110 | Principles of Computing | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science | |

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Core (6 courses, 54 units)

| | | |
|-----------|--|---|
| 36-202 | Methods for Statistics & Data Science | 9 |
| or 36-290 | Introduction to Statistical Research Methodology | |
| 36-235 | Probability and Statistical Inference I - (recommended) | 9 |
| or 36-225 | Introduction to Probability Theory | |
| 36-236 | Probability and Statistical Inference II - (recommended) | 9 |
| or 36-226 | Introduction to Statistical Inference | |
| 36-350 | Statistical Computing | 9 |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Special Topics and Electives (3 courses, 27 units)

Students must take a total of three courses from Special Topics (numbered 36-46x) and Statistics Electives listed below. Students will consult with the concentration advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-46x | Special Topics (topics and offerings vary) | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Statistics & Machine Learning Concentration

(87 units minimum)

In the BHA concentration in Statistics & Machine Learning, develop and master a wide array of skills in computing, mathematics, statistical theory, and the interpretation and display of complex data. In addition, students with a BHA concentration in Statistics & Machine Learning gain experience in applying statistical tools to real problems in other fields and learn the nuances of interdisciplinary collaboration. This program is geared towards students interested in statistical computation, data science or "Big Data" problems.

Prerequisites

These five courses are not counted as part of your DC Concentration. They may be used to satisfy general education or free elective requirements.

| | | |
|-----------|--|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| 21-256 | Multivariate Analysis | 9 |
| or 21-259 | Calculus in Three Dimensions | |
| 21-240 | Matrix Algebra with Applications | 10 |
| or 21-241 | Matrices and Linear Transformations | |
| or 21-242 | Matrix Theory | |
| 15-112 | Fundamentals of Programming and Computer Science | 12 |

Note: 21-240, 21-241, 21-242 must be completed before taking 36-401 Modern Regression. 21-241 and 21-242 are intended only for students with a very strong mathematical background.

Statistics Core (5 courses, 45 units)

| | | |
|-----------|--|---|
| 36-235 | Probability and Statistical Inference I - (recommended) | 9 |
| or 36-225 | Introduction to Probability Theory | |
| 36-236 | Probability and Statistical Inference II - (recommended) | 9 |
| or 36-226 | Introduction to Statistical Inference | |
| 36-350 | Statistical Computing | 9 |
| 36-401 | Modern Regression | 9 |
| 36-402 | Advanced Methods for Data Analysis | 9 |

Data Analysis Electives (1 course, 9 units)

Students must take one course from the Statistics Electives listed below. Students will consult with the concentration advisor to select the Special Topics and Electives courses that best fit for their areas of interest.

| | | |
|--------|---|---|
| 36-303 | Sampling, Survey and Society | 9 |
| 36-311 | Statistical Analysis of Networks | 9 |
| 36-313 | Statistics of Inequality and Discrimination | 9 |
| 36-315 | Statistical Graphics and Visualization | 9 |
| 36-318 | Introduction to Causal Inference | 9 |
| 36-46x | Special Topics (topics and offerings vary) | 9 |
| 36-490 | Undergraduate Research | 9 |
| 36-493 | Sports Analytics Capstone | 9 |
| 36-497 | Corporate Capstone Project | 9 |

Machine Learning Core (2 courses, 24 units)

| | | |
|--------|---|----|
| 15-122 | Principles of Imperative Computation -(C or higher) | 12 |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |

Machine Learning Elective (1 course, 9 units minimum)

Students must take one course from the ML Electives listed below. Students will consult with the Statistics & Machine Learning advisor to choose an elective that best fits their area of interest. This course may have additional pre-requisites. Keep in mind this is not an exhaustive list and other applicable courses can be reviewed to be approved as an ML elective - please speak with the concentration advisor about this.

| | | |
|---------------|---|----|
| 02-510/710 | Computational Genomics | 12 |
| 05-317 | Design of Artificial Intelligence Products | 12 |
| 05-434/11-344 | Machine Learning in Practice | 12 |
| 10-403/703 | Deep Reinforcement Learning & Control | 12 |
| 10-405/605 | Machine Learning with Large Datasets (Undergraduate) | 12 |
| 10-414 | Deep Learning Systems: Algorithms and Implementation | 12 |
| 10-417 | Intermediate Deep Learning | 12 |
| 10-418/618 | Machine Learning for Structured Data | 12 |
| 10-613 | Machine Learning Ethics and Society | 12 |
| 10-707 | Advanced Deep Learning | 12 |
| 10-708 | Probabilistic Graphical Models | 12 |
| 11-324/624 | Human Language for Artificial Intelligence | 12 |
| 11-411 | Natural Language Processing | 12 |
| 11-441 | Machine Learning for Text and Graph-based Mining | 9 |
| 11-485 | Introduction to Deep Learning | 9 |
| 11-661/761 | Language and Statistics | 12 |
| 15-281 | Artificial Intelligence: Representation and Problem Solving | 12 |
| 15-386 | Neural Computation | 9 |

| | | |
|------------|---|----|
| 15-387 | Computational Perception | 9 |
| 15-482 | Autonomous Agents | 12 |
| 16-311 | Introduction to Robotics | 12 |
| 16-385/720 | Computer Vision | 12 |
| 17-445 | Machine Learning in Production | 12 |
| 85-419 | Introduction to Parallel Distributed Processing | 9 |

Technical Writing Concentration

(87 units minimum)

The concentration in Technical Writing is specifically designed to prepare students for successful careers involving scientific, technical, and computer-related communication, including writing and designing for digital media. Technical communicators develop and design web sites, explain science and technology to the public, develop print and multimedia materials, develop information management systems, design and deliver corporate training, and develop support systems for consumer products ranging from software for word processing or personal finances to complex data management systems. The Technical Writing concentration includes with a common core of foundation courses in print and on-line communication as well as a set of prerequisites in math, statistics and computer programming.

Students with a Technical Writing concentration take two Theory/Specialization courses specific to either the Technical Communication (TC) or the Scientific and Medical Communication (SMC) track. In addition, students in the SMC track take two courses in the natural sciences or engineering relevant to their areas of interest, while TC students take two electives in management, technology and social issues.

Prerequisite Courses

| | | |
|-----------|--|----|
| 21-111 | Calculus I | 10 |
| or 21-112 | Calculus II | |
| or 21-120 | Differential and Integral Calculus | |
| or 21-127 | Concepts of Mathematics | |
| 15-110 | Principles of Computing (recommended for SMC-track students) | 10 |
| or 15-112 | Fundamentals of Programming and Computer Science (recommended for TC-track students) | |

Technical Writing Core Courses (6 courses, 51 units)

| | | |
|--------|---|----|
| 76-26x | Introductory Genre Writing Course (Nonfiction, Fiction, Poetry or Screenwriting) | 9 |
| 76-271 | Introduction to Professional and Technical Writing | 9 |
| 76-300 | Professional Seminar | 3 |
| 76-390 | Style | 9 |
| 76-391 | Document & Information Design | 9 |
| 76-487 | Web Design - Information Architecture & Content Strategy (formerly titled Web Design) | 12 |

Theory/Specialization Courses (3 courses, 27 units minimum)

Complete three courses to deepen your area of specialty in Technical Communication or Scientific and Medical Communication. One course must be chosen from among courses designated as Recommended Options. Check with the English department each semester for additional options.

Recommended Options:

| | | |
|--------|---|----|
| 76-314 | Data Stories | 9 |
| 76-327 | Equity & Communication: Strategies for Institutional Change | 9 |
| 76-380 | Methods in Humanities Analytics | 9 |
| 76-395 | Science Writing | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-474 | Software Documentation | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-491 | Rhetorical Analysis | 9 |
| 76-494 | Healthcare Communications | 9 |

Additional Options include but are not limited to the following:

| | | |
|--------|---|------|
| 76-301 | Internship | Var. |
| 76-302 | Communication Support Tutoring Practicum | 6 |
| 76-318 | Communicating in the Global Marketplace | 9 |
| 76-325 | Intertextuality | 9 |
| 76-327 | Equity & Communication: Strategies for Institutional Change | 9 |

| | | |
|--------|---|----|
| 76-351 | Rhetorical Invention | 9 |
| 76-354 | Watchdog Journalism | 9 |
| 76-360 | Literary Journalism Workshop | 9 |
| 76-372 | News Writing | 9 |
| 76-384 | Race, Nation, and the Enemy | 9 |
| 76-389 | Rhetorical Grammar | 9 |
| 76-391 | Document & Information Design | 9 |
| 76-395 | Science Writing | 9 |
| 76-425 | Rhetoric, Science, and the Public Sphere | 9 |
| 76-474 | Software Documentation | 9 |
| 76-475 | Law, Performance, and Identity | 9 |
| 76-476 | Rhetoric of Science | 9 |
| 76-481 | Introduction to Multimedia Design | 12 |
| 76-484 | Discourse Analysis | 9 |
| 76-487 | Web Design - Information Architecture & Content Strategy (formerly titled Web Design) | 12 |
| 39-605 | Engineering Design Projects | 12 |

Electives (1 course, 9 units)

Students with a Technical Writing concentration take one course outside of English to deepen their area of specialty in their track. Typically, students in the SMC track select courses in the natural sciences, computer science, math or statistics, or (for example) healthcare-related courses in the Heinz School. Students in the TC track typically select courses from business, design, psychology, and social and decision sciences, or HCI. Students should work with the concentration advisor to select courses that are meaningful for their track.

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-114 units minimum)

BHA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

| | | |
|-----------|---|-------|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year | 10-15 |
| or 48-095 | Spatial Concepts for Non-Architecture Majors | |
| 62-122 | Digital Media I -Fall, Freshman year | 6 |
| 62-125 | Drawing I -Fall, Freshman year | 6 |
| 62-123 | Digital Media II -Spring, Freshman year | 6 |
| 62-126 | Drawing II -Spring, Freshman year | 6 |
| 48-240 | History of World Architecture, I -Spring, Freshman year | 9 |
| 48-241 | History of Modern Architecture -Fall, Sophomore year | 9 |

Architecture Electives (56 units minimum)

A minimum of **56** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

| | | |
|--------|-------------------------------------|---|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
|--------|-------------------------------------|---|

Foundation Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-135 | Foundations: Sculpture II | 10 |

| | | |
|--------|--------------------------|----|
| 60-150 | Foundations: Drawing | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

Intermediate Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|------------------------------|----|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

| | | |
|--|-------------------------------------|----|
| 60-401/402 | Senior Studio | 10 |
| 60-403 | Senior Critique Seminar | 10 |
| Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) | | 10 |
| Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) | | 10 |
| Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) | | 10 |
| Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) | | 10 |
| 60-499 | Studio Independent Study (one only) | 10 |

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

| | | |
|--------|---------------------------------------|---|
| 60-107 | Foundations: Critical Studies -Spring | 9 |
| 60-3xx | Critical Studies Elective | 9 |

Review Requirement (1 required review, 0 units)

Complete required review:

| | | |
|--------|---|---|
| 60-200 | Sophomore Review -Spring (pass/no pass) | 0 |
|--------|---|---|

Design Concentration

(108 units minimum)

Design Required Courses (16 courses, 98 units)

| | | |
|--|---|---------|
| 51-101 | Studio: Survey of Design -Fall, First-year | 10 |
| 51-121 | Visualizing -Fall, First-year | 10 |
| 51-175 | Design Studies: Place -Fall, First-year (mini-1) | 5 |
| 51-177 | Design Studies: Histories -Fall, First-year (mini-2) | 5 |
| 51-102 | Design Lab -Spring, First-year | 10 |
| 51-122 | Collaborative Visualizing -Spring, First-year | 10 |
| 51-176 | Design Studies: Futures -Spring, First-year (mini-3) | 5 |
| 51-178 | Design Studies: Experience -Spring, First-year (mini-4) | 5 |
| 51-277 | Design Studies: Systems -Fall, Sophomore year (mini-1) | 5 |
| 51-279 | Design Studies: Cultures -Fall, Sophomore year (mini-2) | 5 |
| 51-282 | Design Studies: Persuasion -Spring, Sophomore year (mini-3) | 5 |
| 51-284 | Design Studies: Power -Spring, Sophomore year (mini-4) | 5 |
| Choose Two Studios -Fall, Sophomore year: | | 4.5+4.5 |
| 51-225 | Communications Studio I: Understanding Form & Context | 4.5 |
| or 51-245 | Products Studio I: Understanding Form & Context | |
| or 51-265 | Environments Studio I: Understanding Form & Context | |
| Choose Two Corresponding Labs -Fall, Sophomore year: | | 4.5+4.5 |
| 51-227 | Prototyping Lab I: Communications | 4.5 |
| or 51-247 | Prototyping Lab I: Products | |
| or 51-267 | Prototyping Lab I: Environments | |

Design Electives (10 units)

A minimum of 10 additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(108 units minimum)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Required Courses for All Concentration Options (4 courses, 19 units)

| | | |
|--------|--|---|
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II (prerequisite: 54-177) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (optional) | 6 |

Work with Drama Faculty Area Chair to Approve Concentration Option (89 units minimum).

Design Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional Design units must be approved by the Design faculty area chair. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 64 units)

| | | |
|---------------|---|----|
| 54-121-54-122 | Directing I: A Director's Mindset - Directing I: A Director's Preparation | 18 |
| 54-221-54-222 | Directing II: In the Studio - Directing II: In The Room | 18 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-517 | Directors Common Hour (four times) | 16 |

A minimum of 25 additional Directing units must be approved by the Directing faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 59 units minimum)

| | | |
|---------------|---|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-200-54-200 | Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled) | 2 |
| 54-xxx | Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more) | 18 |

A minimum of 30 additional Dramaturgy units must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional PTM units must be approved by the PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

| | | |
|-----------|-----------------|---|
| 57-152 | Harmony I | 9 |
| or 57-149 | Basic Harmony I | |

Work with Music Advisor to Approve Concentration Option (99 units minimum).

Audio Recording & Production Required Courses (7 courses, 40 units)

| | | |
|-----------|--|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Choose **59** units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-161 | Eurhythmics I | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-427 | Advanced Seminar in Film Musicology | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-622 | Independent Study in Sound Recording Production | 3 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (12 courses, 76 units)

| | | |
|-----------|--|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (12 courses, 76 units)

| | | |
|-----------|--|---|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |

| | | |
|--------|--|----|
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (7 courses, 47 units)

| | | |
|-----------|--|----|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 57-911 | Music Since 1945 | 9 |
| 57-616 | Independent Study in Sound Studies | 9 |

Choose 52 units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music (prerequisite: 15-112) | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-343 | Music, Technology, and Culture | 9 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music (prerequisite: 57-101 or 57-171) | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-438 | Multitrack Recording | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDeATe minor may double-count up to two of the IDeATe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 4-7 courses, 31-63 units)

Take any Carnegie Mellon course. Many BHA students use their electives to broaden or deepen their concentrations. A maximum of 9 units of physical education and/or military science may be counted toward this requirement.

Bachelor of Science and Arts Degree Program

The Bachelor of Science and Arts (BSA) intercollege degree program combines the strengths of the College of Fine Arts (CFA) and the Mellon College of Science (MCS). This degree is designed for students who are gifted in both the fine arts and the natural sciences or mathematics, and who have the interest and the exceptional ability to pursue both disciplines simultaneously. Students choose their arts concentration from the following schools in CFA: Architecture, Art, Design, Drama or Music. Students choose their science concentration from among the departments in MCS: Biological Sciences, Chemistry, Environmental & Sustainability Studies, Mathematical Sciences, Neurobiology or Physics.

The BSA curriculum has three main components: general core requirements, fine arts concentration requirements and natural sciences/mathematics concentration requirements. Each student's course of study is structured so they can complete this rigorous program in four years.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the primary advisors and liaisons between CFA and MCS. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and an advisor in MCS to guide their focus in the sciences.

BSA Curriculum

| | Units |
|--------------------------------------|----------------|
| I. BSA General Education | 129 |
| II. MCS Concentration | 114-145 |
| III. CFA Concentration | 108-114 |
| IV. Free Electives | 0-29 |
| Total BSA Degree Requirements | 380 |

BSA General Education

(18 courses, 129 units minimum)

- Mathematics (2 courses, 20 units, 21-120 and 21-122 or 21-124 required)
- Science (3 courses, 31 units, 03-121, 09-105, and 33-121 or 33-151 required)
- First-year Courses (2 courses, 12 units, 76-101 and 99-101 required)
- ENGAGE (3 courses, 3 units)
- Cultural/Global Understanding (1 course, 9 units)
- Humanities and Social Sciences (2 courses, 18 units)
- BXA Required Courses (5 courses, 36 units, 52-190, 52-291, 52-392, 52-401, 52-402)

Technical Breadth Requirements (5 courses, 51 units)

As a 21st Century practicing scientist or mathematician, our graduates will work with others from a variety of technical backgrounds. Therefore, all of our students will be broadly trained within the technical fields of science and math. Students will fulfill this training by completing five (5) introductory technical courses in the Mellon College of Science at Carnegie Mellon University.

A student must take the five (5) courses listed below. AP/IB/Cambridge credit may be used to fulfill some of these requirements, but STEM electives must be taken at CMU or at another university for transfer credit to reach the total of five (5) Technical Breadth courses. A list of STEM electives can be found in the MCS general education requirements (p.).

Mathematics (2 courses, 20 units)

| | | |
|-----------|---|----|
| 21-120 | Differential and Integral Calculus | 10 |
| 21-122 | Integration and Approximation | 10 |
| or 21-124 | Calculus II for Biologists and Chemists | |

Science (3 courses, 31 units)

| | | |
|-----------|------------------------------------|----|
| 03-121 | Modern Biology | 9 |
| 09-105 | Introduction to Modern Chemistry I | 10 |
| 33-121 | Physics I for Science Students | 12 |
| or 33-151 | Matter and Interactions I | |

Nontechnical Breadth Requirements (8 courses, 42 units)

MCS aspires for all of our undergraduates to leave our campus with a strong sense of personal integrity, social responsibility, ethics, working with diverse others, global engagement, and personal health and well-being. The following non-technical breadth requirements will require students to develop a personalized plan for their course selection and meta-curricular participation to maximize their CMU experience. Our graduates will be well trained to be life-long and life-wide learners that will lead the scientific community and the world at large.

All candidates for BSA degree must complete the following non-technical breadth requirements:

First-year Courses (2 courses, 12 units)

| | | |
|-----------|---|---|
| 76-101 | Interpretation and Argument | 9 |
| or 76-102 | Advanced First Year Writing: Special Topics | |

- or 76-106 Writing about Literature, Art and Culture
- & 76-107 and Writing about Data
- & 76-108 and Writing about Public Problems

All undergraduate students must complete the First-Year Writing requirement—the Department of English does not accept any Advanced Placement exemptions. This requirement can be completed in two different ways. Enroll in one of two full-semester courses 101 or 102 (by invitation only), 9 units, or enroll in two of three half-semester mini courses (back-to-back within a single semester) 106/107/108, 4.5 + 4.5 units. Course options and topics: www.cmu.edu/hss/english/first_year/index.html

| | | |
|--------|-----------------------------|---|
| 99-101 | Computing @ Carnegie Mellon | 3 |
|--------|-----------------------------|---|

ENGAGE (3 courses, 3 units)

The ENGAGE courses are self-directed learning opportunities (using the MyCORE online platform) designed to enhance students' engagement with wellness and community service. Choose three courses from the list below:

| | | |
|--------|-------------------------------------|---|
| 38-110 | ENGAGE in Service | 1 |
| 38-230 | ENGAGE in Wellness: Looking Inward | 1 |
| 38-330 | ENGAGE in Wellness: Looking Outward | 1 |
| 38-430 | ENGAGE in Wellness: Looking Forward | 1 |

Cultural/Global Understanding (1 course, 9 units)

Cultural or global understanding course(s) may be taken at any time. Nine (9) or more units from the following group of courses will fulfill this requirement. Any student who finds an appropriate Carnegie Mellon course not on the list below that might fulfill this requirement should contact their academic advisor to review the course description to determine if it can be substituted. Cultural and global understanding courses that are taken while studying abroad can be used to fulfill this category. In addition, transfer courses will also be considered for this category. However, this course requirement cannot be satisfied with AP/IB/Cambridge exam credit.

| | | |
|--------|---|---|
| 57-173 | Survey of Western Music History | 9 |
| 57-209 | The Beatles | 9 |
| 57-306 | World Music | 9 |
| 70-342 | Managing Across Cultures | 9 |
| 76-221 | Books You Should Have Read By Now | 9 |
| 76-232 | Introduction to Black Literature | 9 |
| 76-239 | Introduction to Film Studies | 9 |
| 76-241 | Introduction to Gender Studies | 9 |
| 76-386 | Language & Culture | 9 |
| 79-145 | Genocide and Weapons of Mass Destruction | 9 |
| 79-189 | Democracy and History: Thinking Beyond the Self | 9 |
| 79-201 | Introduction to Anthropology | 9 |
| 79-202 | Flesh and Spirit: Early Modern Europe, 1400-1750 | 9 |
| 79-205 | 20th Century Europe | 9 |
| 79-208 | Witchcraft and Witch-Hunting | 9 |
| 79-211 | Modern Southeast Asia: Colonialism, Capitalism, and Cultural Exchange | 9 |
| 79-223 | Mexico: From the Aztec Empire to the Drug War | 9 |
| 79-227 | Modern Africa: The Slave Trade to the End of Apartheid | 9 |
| 79-229 | The Origins of the Palestinian-Israeli Conflict, 1880-1948 | 9 |
| 79-230 | The Arab-Israeli Conflict and Peace Process since 1948 | 9 |
| 79-232 | Arabian Peninsula Environmental History | 9 |
| 79-234 | Technology and Society | 9 |
| 79-240 | Development of American Culture | 9 |
| 79-241 | African American History: Africa to the Civil War | 9 |
| 79-242 | African American History: Reconstruction to the Present | 9 |
| 79-244 | Women in American History | 9 |
| 79-245 | Capitalism and Individualism in American Culture | 9 |
| 79-261 | The Last Emperors: Chinese History and Society, 1600-1900 | 9 |
| 79-262 | Modern China: From the Birth of Mao ... to Now | 9 |
| 79-263 | Mao and the Chinese Cultural Revolution | 9 |
| 79-265 | Russian History: Game of Thrones | 9 |
| 79-266 | Russian History and Revolutionary Socialism | 9 |

| | | |
|--------|---|---|
| 79-267 | The Soviet Union in World War II: Military, Political, and Social History | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-280 | Coffee and Capitalism | 9 |
| 79-283 | Hungry World: Food and Famine in Global Perspective | 9 |
| 79-343 | Education, Democracy, and Civil Rights | 9 |
| 79-345 | Roots of Rock & Roll | 9 |
| 79-350 | Early Christianity | 9 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 80-100 | Introduction to Philosophy | 9 |
| 80-250 | Ancient Philosophy | 9 |
| 80-251 | Modern Philosophy | 9 |
| 80-253 | Continental Philosophy | 9 |
| 80-254 | Analytic Philosophy | 9 |
| 80-255 | Pragmatism: Making Ideas Work | 9 |
| 80-276 | Philosophy of Religion | 9 |
| 82-xxx | Any course from Modern Languages | 9 |
| 84-380 | US Grand Strategy | 9 |

Humanities and Social Sciences (2 courses, 18 units)

To fulfill this requirement, students must complete a minimum of two (2) nontechnical courses totaling at least 18 units in the Tepper School of Business and/or the Dietrich College of Humanities and Social Sciences. Courses counted toward the Cultural/Global Understanding requirement, and 76-101, do not count toward this requirement.

Check our web site for courses from DC, CFA, and Tepper that may NOT be used (<http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/deletions.html>) to satisfy this requirement because they are too technical in nature, plus a list of courses in other colleges (including SCS, CIT, Tepper, and Heinz College) that do satisfy (<http://www.cmu.edu/mcs/undergrad/advising/hss-finearts/additions.html>) this requirement.

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

| | | |
|--------|--|-----|
| 52-190 | BXA Seminar I: Building the Wunderkammer - Spring, Freshman (mini-4) | 4.5 |
| 52-291 | BXA Seminar II: Transferring Knowledge -Spring, Sophomore (mini-3) | 4.5 |
| 52-392 | BXA Seminar III: Deconstructing Disciplines | 9 |
| 52-401 | BXA Seminar IV: Capstone Project Research | 9 |
| 52-402 | BXA Seminar V: Capstone Project Production | 9 |

Mellon College of Science Concentration

(number of courses vary, 114-144 units)

BSA students declare one of the following concentrations, through consultation with their BXA advisor and the MCS concentration advisors. A completed MCS Concentration Declaration form must be approved by the concentration advisor and submitted to the BXA office, by spring mid-semester break of the student's first year.

Note: The BSA Physics concentration requires additional coursework totaling the degree requirements beyond 380 units.

- Biological Sciences (114 units)
- Chemistry (121 units)
- Environmental & Sustainability Studies (123 units)
- Mathematical Sciences (127 units)
- Neurobiology (114 units)
- Physics (145 units)

BSA students who are admitted as freshmen are undeclared until they have met with a concentration advisor and have submitted their signed Declaration form. BSA students who are admitted through internal transfer must have chosen an MCS concentration at the time of their application (which serves as declaration). All BSA students wishing to change their MCS concentration at any time following the initial declaration must meet with the advisor of their intended concentration area to complete a new Declaration form.

Biological Sciences Concentration

(114 units minimum)

Biological Sciences Required Courses (11 courses, 96 units minimum)

| | | |
|-----------|--|----|
| 03-201 | Undergraduate Colloquium for Sophomores | 2 |
| 03-220 | Genetics - Fall, Sophomore year | 9 |
| 03-231 | Honors Biochemistry - Spring, Sophomore year | 9 |
| 03-320 | Cell Biology - Fall, Junior year | 9 |
| 03-343 | Experimental Techniques in Molecular Biology - Fall, Junior year | 12 |
| 09-106 | Modern Chemistry II | 10 |
| 09-207 | Techniques in Quantitative Analysis | 9 |
| 09-208 | Techniques for Organic Synthesis and Analysis | 9 |
| or 03-344 | Experimental Biochemistry | |
| or 03-345 | Experimental Cell and Developmental Biology | |
| or 03-346 | Experimental Neuroscience | |
| 09-217 | Organic Chemistry I | 9 |
| 09-218 | Organic Chemistry II | 9 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |

Biological Sciences Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher, excluding 03-445 and 03-545.

Chemistry Concentration

(118 units minimum)

Chemistry Required Courses (13 courses, 100 units)

| | | |
|---------------|--|----|
| 09-106 | Modern Chemistry II | 10 |
| 09-219 | Modern Organic Chemistry | 10 |
| 09-220 | Modern Organic Chemistry II | 10 |
| 09-331 | Modern Analytical Instrumentation | 9 |
| 09-348 | Inorganic Chemistry | 10 |
| 09-221 | Laboratory I: Introduction to Chemical Analysis | 12 |
| 09-222 | Laboratory II: Organic Synthesis and Analysis | 12 |
| 09-321 | Laboratory III: Molecular Design and Synthesis | 12 |
| or 09-323 | Bioorganic Chemistry Laboratory | |
| 09-201-09-202 | Undergraduate Seminar I - Undergraduate Seminar II: Safety and Environmental Issues for Chemists - Undergraduate Seminar III | 3 |
| 09-402 | Undergraduate Seminar VI | 3 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |

Note: Students who have a strong chemistry background, should enroll in 09-107 rather than 09-105. Students who complete 09-107 with an "A" grade will be exempted from the requirement to take 09-106 Modern Chemistry II.

Advanced Chemistry Electives (2 courses, 18 units)

May be any upper level chemistry course, 09-3xx or higher, or Biochemistry I, 03-231 or 03-232, with the exception of 09-435 Independent Study, which can be used only by permission of the Director of Undergraduate Studies.

Environmental & Sustainability Studies Concentration

(123 units minimum)

Additional Required Courses (2 courses, 18 units minimum)

| | | |
|-----------|---|---|
| 09-217 | Organic Chemistry I | 9 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| or 33-142 | Physics II for Engineering and Physics Students | |

Core Courses (4 courses, 30 units)

| | | |
|-----------|--|---|
| 24/09-291 | Environmental Systems on a Changing Planet | 9 |
| 24/09-381 | Environmental Systems on a Changing Planet: Science & Engineering Addendum (co-req: 24-291/09-291) | 3 |
| 66-236 | Introduction to Environmental Ideas | 9 |
| 66-506 | Senior Capstone (Interdisciplinary Research: Capstone in ESS) | 9 |

Earth and Environmental Science (1 course, 9 units)

Choose one course from the list below.

| | | |
|--------|--|---|
| 03-128 | Biology for Life Special Topics (Section S, Tropical Ecology) | 9 |
| 03-140 | Ecology and Environmental Science | 9 |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 09-510 | Chemistry and Sustainability * | 9 |
| 09-524 | Environmental Chemistry * | 9 |
| 09-529 | Introduction to Sustainable Energy Science * | 9 |
| 09-538 | Exposure and Risk Assessment for Environmental Pollutants | 9 |
| 33-226 | Physics of Energy * | 9 |

* Prerequisites from the BSA general education curriculum

Global Course (1 course, 3 units)

| | | |
|--------|--|---|
| 99-xxx | Each semester, a new course is offered on Global themes, in partnership with University of Pittsburgh's Global Studies Center. | 3 |
|--------|--|---|

Statistics and Data Science (1 course, 9 units)

| | | |
|--------|-----------------------|---|
| 36-xxx | Any Statistics Course | 9 |
|--------|-----------------------|---|

Political Economy (1 course, 9 units minimum)

Choose one course from the list below.

| | | |
|--------|---|----|
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 79-300 | History of American Public Policy | 9 |
| 84-110 | Foundations of Political Economy | 9 |
| 84-226 | International Relations | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 88-344 | Systems Analysis: Environmental Policy | 9 |

Electives (5 courses, 45 units minimum)

Choose three MCS Electives and two DC Electives in consultation with the concentration advisor.

MCS Electives:

| | | |
|--------|--|----|
| 03-140 | Ecology and Environmental Science | 9 |
| 09-225 | Climate Change: Chemistry, Physics and Planetary Science | 9 |
| 09-510 | Chemistry and Sustainability | 9 |
| 09-524 | Environmental Chemistry * | 9 |
| 09-529 | Introduction to Sustainable Energy Science | 9 |
| 12-100 | Exploring CEE: Infrastructure and Environment in a Changing World | 12 |
| 12-201 | Geology | 9 |
| 19-101 | Introduction to Engineering and Public Policy | 12 |
| 19-425 | Sustainable Energy for the Developing World | 9 |
| 24-292 | Renewable Energy Engineering | 9 |
| 27-505 | Exploration of Everyday Materials | 9 |
| 33-226 | Physics of Energy | 9 |

DC Electives:

| | | |
|--------|--|---|
| 76-241 | Introduction to Gender Studies | 9 |
| 76-291 | Getting Heard/Making a Difference | 9 |
| 76-354 | Watchdog Journalism | 9 |
| 76-395 | Science Writing * | 9 |
| 76-450 | Law, Culture, and the Humanities | 9 |
| 79-201 | Introduction to Anthropology | 9 |
| 79-275 | Introduction to Global Studies | 9 |
| 79-278 | How (Not) to Change the World | 9 |
| 79-288 | Bananas, Baseball, and Borders: Latin America and the United States | 9 |
| 79-297 | Technology and Work | 9 |
| 79-331 | Body Politics: Women and Health in America | 9 |
| 79-372 | The Rise and Fall of Pittsburgh Steel | 6 |
| 79-377 | Food, Culture, and Power: A History of Eating | 9 |
| 79-379 | Extreme Ethnography | 9 |
| 79-383 | The History of Capitalism | 9 |
| 80-135 | Introduction to Political Philosophy | 9 |
| 80-244 | Environmental Ethics | 9 |

| | | |
|--------|--------------------------------------|---|
| 84-110 | Foundations of Political Economy | 9 |
| 84-275 | Comparative Politics | 9 |
| 84-325 | Contemporary American Foreign Policy | 9 |
| 85-241 | Social Psychology | 9 |

* Additional prerequisites

Mathematical Sciences Concentration

(127 units minimum)

Mathematical Sciences Required Courses (9 courses, 91 units minimum)

(Reasonable substitutions within the core program will be allowed.)

| | | |
|-----------|---|----|
| 15-110 | Principles of Computing | 10 |
| 21-127 | Concepts of Mathematics | 12 |
| or 21-128 | Mathematical Concepts and Proofs | |
| 21-228 | Discrete Mathematics | 9 |
| 21-241 | Matrices and Linear Transformations | 11 |
| or 21-242 | Matrix Theory | |
| 21-259 | Calculus in Three Dimensions | 10 |
| or 21-268 | Multidimensional Calculus | |
| 21-260 | Differential Equations | 9 |
| or 21-261 | Introduction to Ordinary Differential Equations | |
| or 33-231 | Physical Analysis | |
| 21-355 | Principles of Real Analysis I | 9 |
| 21-373 | Algebraic Structures | 9 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| or 33-152 | Matter and Interactions II | |

Mathematical Sciences Electives (2 courses, 18 units)

Students with a Music concentration should take 21-469 Computational Introduction to Partial Differential Equations.

Mathematical Sciences, Statistics, or Computer Science Electives (2 courses, 18 units)

May be computer science course above the 100-level, mathematical science courses beyond the calculus sequence, and statistics courses at the level of 36-225 or higher.

Neurobiology Concentration

(114 units minimum)

Neurobiology Required Courses (12 courses, 96 units)

| | | |
|-----------|--|----|
| 03-161 | Molecules to Mind | 9 |
| or 85-219 | Foundations of Brain and Behavior | |
| 03-201 | Undergraduate Colloquium for Sophomores | 2 |
| 03-220 | Genetics - Fall, Sophomore year | 9 |
| 03-231 | Honors Biochemistry - Spring, Sophomore year | 9 |
| 03-320 | Cell Biology - Fall, Junior year | 9 |
| 03-342 | Introduction to Biological Laboratory Practices - Fall, Junior year | 1 |
| 03-343 | Experimental Techniques in Molecular Biology - Fall, Junior year | 12 |
| 03-362 | Cellular Neuroscience | 9 |
| 03-363 | Systems Neuroscience | 9 |
| 09-217 | Organic Chemistry I | 9 |
| 33-122 | Physics II for Biological Sciences & Chemistry Students | 9 |
| 85-211 | Cognitive Psychology | 9 |

Neurobiology Electives (2 courses, 18 units)

One course must be an advanced elective selected from 03-3xx or higher.

Physics Concentration (145 units minimum)**Physics Required Courses (16 courses, 127 units)**

| | | |
|-----------|---|----|
| 21-259 | Calculus in Three Dimensions | 10 |
| 33-104 | Experimental Physics | 9 |
| 33-142 | Physics II for Engineering and Physics Students | 12 |
| or 33-152 | Matter and Interactions II | |
| 33-201 | Physics Sophomore Colloquium I -Fall | 2 |
| 33-202 | Physics Sophomore Colloquium II -Spring | 2 |
| 33-211 | Physics III: Modern Essentials | 10 |

| | | |
|--------|--|----|
| 33-228 | Electronics I | 10 |
| 33-231 | Physical Analysis | 10 |
| 33-232 | Mathematical Methods of Physics | 10 |
| 33-234 | Quantum Physics | 10 |
| 33-301 | Physics Upperclass Colloquium I -Fall | 1 |
| 33-302 | Physics Upperclass Colloquium II -Spring | 1 |
| 33-331 | Physical Mechanics I | 10 |
| 33-338 | Intermediate Electricity and Magnetism I | 10 |
| 33-340 | Modern Physics Laboratory | 10 |
| 33-341 | Thermal Physics I | 10 |

Qualifying Physics Electives (2 courses, 18 units)

Two 33-xxx qualifying physics elective courses (<http://coursecatalog.web.cmu.edu/schools-colleges/melloncollegeofscience/departmentofphysics/#physicsselectivestextcontainer>) pre-approved by the Physics Department. 33-114 Physics of Musical Sound is highly recommended for students with a Music concentration.

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-114 units minimum)

BSA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Design (108 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

| | | |
|-----------|---|-------|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year | 10-15 |
| or 48-095 | Spatial Concepts for Non-Architecture Majors | |
| 62-122 | Digital Media I -Fall, Freshman year | 6 |
| 62-125 | Drawing I -Fall, Freshman year | 6 |
| 62-123 | Digital Media II -Spring, Freshman year | 6 |
| 62-126 | Drawing II -Spring, Freshman year | 6 |
| 48-240 | History of World Architecture, I -Spring, Freshman year | 9 |
| 48-241 | History of Modern Architecture -Fall, Sophomore year | 9 |

Architecture Electives (56 units minimum)

A minimum of **56** additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

| | | |
|--------|-------------------------------------|---|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
|--------|-------------------------------------|---|

Foundation Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-135 | Foundations: Sculpture II | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

Intermediate Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|------------------------------|----|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

| | | |
|---|-------------------------------------|----|
| 60-401/402 | Senior Studio | 10 |
| 60-403 | Senior Critique Seminar | 10 |
| Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429)* | | 10 |
| Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447)* | | 10 |
| Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449)* | | 10 |
| Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498)* | | 10 |
| 60-499 | Studio Independent Study (one only) | 10 |

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

| | | |
|--------|---------------------------------------|---|
| 60-107 | Foundations: Critical Studies -Spring | 9 |
| 60-3xx | Critical Studies Elective | 9 |

Review Requirement (1 required review, 0 units)

Complete required review:

| | | |
|--------|---|---|
| 60-200 | Sophomore Review -Spring (pass/no pass) | 0 |
|--------|---|---|

Design Concentration

(108 units minimum)

Design Required Courses (16 courses, 98 units)

| | | |
|--|---|---------|
| 51-101 | Studio: Survey of Design -Fall, First-year | 10 |
| 51-121 | Visualizing -Fall, First-year | 10 |
| 51-175 | Design Studies: Place -Fall, First-year (mini-1) | 5 |
| 51-177 | Design Studies: Histories -Fall, First-year (mini-2) | 5 |
| 51-102 | Design Lab -Spring, First-year | 10 |
| 51-122 | Collaborative Visualizing -Spring, First-year | 10 |
| 51-176 | Design Studies: Futures -Spring, First-year (mini-3) | 5 |
| 51-178 | Design Studies: Experience -Spring, First-year (mini-4) | 5 |
| 51-277 | Design Studies: Systems -Fall, Sophomore year (mini-1) | 5 |
| 51-279 | Design Studies: Cultures -Fall, Sophomore year (mini-2) | 5 |
| 51-282 | Design Studies: Persuasion -Spring, Sophomore year (mini-3) | 5 |
| 51-284 | Design Studies: Power -Spring, Sophomore year (mini-4) | 5 |
| Choose Two Studios -Fall, Sophomore year: | | 4.5+4.5 |
| 51-225 | Communications Studio I: Understanding Form & Context | 4.5 |
| or 51-245 | Products Studio I: Understanding Form & Context | |
| or 51-265 | Environments Studio I: Understanding Form & Context | |
| Choose Two Corresponding Labs -Fall, Sophomore year: | | 4.5+4.5 |
| 51-227 | Prototyping Lab I: Communications | 4.5 |
| or 51-247 | Prototyping Lab I: Products | |
| or 51-267 | Prototyping Lab I: Environments | |

Design Electives (10 units)

A minimum of **10** additional Design units must be approved by the Design advisor. A list of these selected courses must be filed in the BXA office.

Drama Concentration

(108 units minimum)

Options available in the following areas: 1) Design, 2) Directing, 3) Dramaturgy, 4) Production Technology and Management

Required Courses for All Concentration Options (4 courses, 19 units)

| | | |
|--------|--|---|
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II (prerequisite: 54-177) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (optional) | 6 |

Work with Drama Faculty Area Chair to Approve Concentration Option (89 units minimum).

Design Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional Design units must be approved by the Design faculty area chair. A list of these selected courses must be filed in the BXA office.

Directing Required Courses (10 courses, 64 units)

| | | |
|---------------|---|----|
| 54-121-54-122 | Directing I: A Director's Mindset - Directing I: A Director's Preparation | 18 |
| 54-221-54-222 | Directing II: In the Studio - Directing II: In The Room | 18 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-517 | Directors Common Hour (four times) | 16 |

A minimum of 25 additional Directing units must be approved by the Directing faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 59 units minimum)

| | | |
|---------------|---|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-200-54-200 | Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled) | 2 |
| 54-xxx | Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more) | 18 |

A minimum of 30 additional Dramaturgy units must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional PTM units must be approved by the PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

| | | |
|-----------|-----------------|---|
| 57-152 | Harmony I | 9 |
| or 57-149 | Basic Harmony I | |

Work with Music Advisor to Approve Concentration Option (99 units minimum).

Audio Recording & Production Required Courses (7 courses, 40 units)

| | | |
|-----------|---|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |

| | | |
|-----------|--|---|
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Choose 59 units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-161 | Eurhythmics I | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-427 | Advanced Seminar in Film Musicology | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-622 | Independent Study in Sound Recording Production | 3 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEATe minor may double-count up to two of the IDEATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (12 courses, 76 units)

| | | |
|-----------|--|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of 23 additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (12 courses, 76 units)

| | | |
|-----------|--|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfege I | 3 |
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of 23 additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (7 courses, 47 units)

| | | |
|-----------|---|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfege I | 3 |

| | | |
|------------------------------|--|----|
| or 57-180 | Basic Solfege I | |
| or 57-185 | Advanced Solfege I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 57-911 | Music Since 1945 | 9 |
| 57-616 | Independent Study in Sound Studies | 9 |
| Choose 52 units from: | | |
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfege II | 3 |
| or 57-186 | Advanced Solfege II | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music (prerequisite: 15-112) | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-343 | Music, Technology, and Culture | 9 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music (prerequisite: 57-101 or 57-171) | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-438 | Multitrack Recording | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEaTe minor may double-count up to two of the IDEaTe minor courses towards the Sound Theory & Practice concentration.

Free Electives

(approximately 0-3 courses, 0-29 units)

Take any Carnegie Mellon course. A maximum of 9 units of physical education and/or military science may be counted toward this requirement. Physical education and military science courses will not be calculated in a student's QPA.

Engineering and Arts Additional Major

The Engineering and Arts (EA) additional major combines the strengths of the College of Fine Arts (CFA) and the College of Engineering (ENG). This additional major provides students with formal practice and training in the creative arts that is more robust than a minor, as well as the foundation of interdisciplinary research to accomplish the integration of their interests. Students who currently have a primary major in engineering, choose their arts concentration from the following schools in CFA: Architecture, Art, Drama or Music.

The EA curriculum has two main components: BXA requirements and fine arts concentration requirements. Each student's course of study is structured so it can be completed alongside their primary engineering major.

Students receive extensive advising support. The academic advisors in the BXA Intercollege Degree Programs are the advisors and liaisons between CFA and Engineering. Each student has two additional academic advisors: an advisor in the admitting school of CFA to guide their focus in the arts and their primary advisor in Engineering to guide their full major in engineering.

EA Curriculum

| | Units |
|---|----------------|
| I. BXA Requirements | 36 |
| II. CFA Concentration | 108-114 |
| Total EA Additional Major Requirements | 144-150 |

BXA Requirements

BXA Required Courses (5 courses, 36 units)

BXA-specific courses give students the opportunity to integrate their areas of concentration by focusing on interdisciplinary approaches and arts-based research techniques.

| | | |
|--------|--|-----|
| 52-190 | BXA Seminar I: Building the Wunderkammer - Spring, Freshman (mini-4) | 4.5 |
| 52-291 | BXA Seminar II: Transferring Knowledge -Spring, Sophomore (mini-3) | 4.5 |
| 52-392 | BXA Seminar III: Deconstructing Disciplines | 9 |
| 52-401 | BXA Seminar IV: Capstone Project Research | 9 |
| 52-402 | BXA Seminar V: Capstone Project Production | 9 |

COLLEGE OF FINE ARTS CONCENTRATION

(number of courses vary, 108-114 units minimum)

EA students choose one of the following concentrations:

- Architecture (108 units)
- Art (114 units)
- Drama (108 units)
- Music (108 units)

Architecture Concentration

(108 units minimum)

Architecture Required Courses (7 courses, 52 units minimum)

| | | |
|-----------|---|-------|
| 48-100 | Architecture Design Studio: POIESIS STUDIO 1 - Fall, Freshman or Sophomore year | 10-15 |
| or 48-095 | Spatial Concepts for Non-Architecture Majors | |
| 62-122 | Digital Media I -Fall, Freshman year | 6 |
| 62-125 | Drawing I -Fall, Freshman year | 6 |
| 62-123 | Digital Media II -Spring, Freshman year | 6 |
| 62-126 | Drawing II -Spring, Freshman year | 6 |
| 48-240 | History of World Architecture, I -Spring, Freshman year | 9 |
| 48-241 | History of Modern Architecture -Fall, Sophomore year | 9 |

Architecture Electives (56 units minimum)

A minimum of 56 additional Architecture units must be approved by the Architecture advisor. A list of these selected courses must be filed in the BXA office.

Art Concentration

(114 units minimum)

First-Year Seminar (1 course, 6 units)

| | | |
|--------|-------------------------------------|---|
| 60-104 | Foundations: Art First-Year Seminar | 6 |
|--------|-------------------------------------|---|

Foundation Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|-------------------------------|----|
| 60-110 | Foundations: Time-Based Media | 10 |
| 60-120 | Foundations: Digital Media | 10 |
| 60-131 | Foundations: Sculpture | 10 |
| 60-135 | Foundations: Sculpture II | 10 |
| 60-150 | Foundations: Drawing | 10 |
| 60-170 | Foundations: Paint/Print | 10 |

Intermediate Studios (3 courses, 30 units)

Complete three courses:

| | | |
|--------|------------------------------|----|
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |
| 60-2xx | Intermediate Studio Elective | 10 |

Advanced Studios (3 courses, 30 units)

Students may take courses in any media area (ETB, SIS, CP or DP3). They may take all courses in one media area if a focus is desired. With approval from the Art advisor, BXA students can take an additional intermediate studio in lieu of an advanced studio to increase breadth.

Complete three courses:

| | | |
|--|-------------------------------------|----|
| 60-401/402 | Senior Studio | 10 |
| 60-403 | Senior Critique Seminar | 10 |
| Advanced Electronic and Time-Based Work (ETB) (course numbers 60-410 through 60-429) | | |
| Advanced Sculpture, Installation and Site-Work (SIS) (course numbers 60-430 through 60-447) | | |
| Advanced Contextual Practice (CP) (course numbers 60-448 through 60-449) | | |
| Advanced Drawing, Painting, Print Media and Photography (DP3) (course numbers 60-450 through 60-498) | | |
| 60-499 | Studio Independent Study (one only) | 10 |

* Courses offered intermittently; speak with a BXA advisor to determine course availability.

Critical Studies (2 courses, 18 units)

| | | |
|--------|---------------------------------------|---|
| 60-107 | Foundations: Critical Studies -Spring | 9 |
| 60-3xx | Critical Studies Elective | 9 |

Review Requirement (1 required review, 0 units)

Complete required review:

| | | |
|--------|---|---|
| 60-200 | Sophomore Review -Spring (pass/no pass) | 0 |
|--------|---|---|

Drama Concentration

(108 units minimum)

Options available in the following areas: 1) Design, 2) Dramaturgy, 3) Production Technology and Management

Required Courses for All Concentration Options (4 courses, 19 units)

| | | |
|--------|--|---|
| 54-175 | Conservatory Hour | 1 |
| 54-177 | Foundations of Drama I | 6 |
| 54-281 | Foundations of Drama II (prerequisite: 54-177) | 6 |
| 54-381 | Special Topics in Drama: History, Literature and Criticism | 6 |
| 54-362 | Anti-Racist & Equitable Practices in Theater (optional) | 6 |

Work with Drama Faculty Area Chair to Approve Concentration Option (89 units minimum).

Design Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional Design units must be approved by the Design faculty area chair. A list of these selected courses must be filed in the BXA office.

Dramaturgy Required Courses (9 courses, 59 units minimum)

| | | |
|---------------|---|----|
| 54-109 | Dramaturgy 1: Approaches to Text | 9 |
| 54-184 | Dramaturgy 2: Introduction to Production Dramaturgy | 9 |
| 54-121 | Directing I: A Director's Mindset | 9 |
| 54-159-54-159 | Production Practicum-Production Practicum (two times) | 12 |
| 54-200-54-200 | Dramaturgy Forum-Dramaturgy Forum -Fall (minimum of two; every semester it is offered while enrolled) | 2 |
| 54-xxx | Dramaturgy 3, 4, 5 or 6 (minimum of two; all four if enrolled as BXA for six semesters or more) | 18 |

A minimum of 30 additional Dramaturgy units must be approved by the Dramaturgy faculty area chair. A list of these selected courses must be filed in the BXA office.

Production Technology and Management Required Courses (2 courses, 26 units)

| | | |
|---------------|---|----|
| 54-151-54-152 | Stagecraft-Stagecraft (13 units + 13 units) | 26 |
|---------------|---|----|

A minimum of 63 additional PTM units must be approved by the PTM faculty area chair. A list of these selected courses must be filed in the BXA office.

Music Concentration

(108 units minimum)

Options available in the following areas: 1) Audio Recording & Production, 2) Composition, 2) Music Performance (instrumental, organ, piano, voice), 4) Sound Theory & Practice

Required Course for All Concentration Options (1 course, 9 units)

| | | |
|-----------|-----------------|---|
| 57-152 | Harmony I | 9 |
| or 57-149 | Basic Harmony I | |

Work with Music Advisor to Approve Concentration Option (99 units minimum).

Audio Recording & Production Required Courses (7 courses, 40 units)

| | | |
|-----------|--|---|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfège I | 3 |
| or 57-180 | Basic Solfège I | |
| or 57-185 | Advanced Solfège I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-438 | Multitrack Recording | 9 |

Choose 59 units from:

| | | |
|-----------|---|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfège II | 3 |
| or 57-186 | Advanced Solfège II | |
| 10-301 | Introduction to Machine Learning (Undergrad) | 12 |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-213 | Introduction to Computer Systems | 12 |
| 15-322 | Introduction to Computer Music | 9 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 33-114 | Physics of Musical Sound | 9 |
| 54-166 | Introduction to Sound Design for Theatre | 6 |
| 54-275 | History of Sound Design | 3 |
| 54-666 | Production Audio | 6 |
| 57-161 | Eurhythmics I | 3 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-427 | Advanced Seminar in Film Musicology | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 57-622 | Independent Study in Sound Recording Production | 3 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEATe minor may double-count up to two of the IDEATe minor courses towards the Audio Recording & Production concentration.

Composition Required Courses (12 courses, 76 units)

| | | |
|-----------|--|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfège I | 3 |
| or 57-180 | Basic Solfège I | |
| or 57-185 | Advanced Solfège I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of 23 additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Music Performance Required Courses (12 courses, 76 units)

| | | |
|-----------|---|----|
| 57-161 | Eurhythmics I (recommended co-requisite: 57-181) | 3 |
| 57-181 | Solfège I | 3 |
| or 57-180 | Basic Solfège I | |
| or 57-185 | Advanced Solfège I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 57-49x | BXA Studio (4 semesters) | 36 |
| 57-xxx | Major Ensemble (4 semesters) | 24 |

A minimum of **23** additional Music units must be approved by the Music advisor. A list of these selected courses must be filed in the BXA office.

Sound Theory & Practice Required Courses (7 courses, 47 units)

| | | |
|-----------|---|----|
| 57-101 | Introduction to Music Technology | 6 |
| or 57-171 | Introduction to Music Technology (self-paced) | |
| 57-181 | Solfège I | 3 |
| or 57-180 | Basic Solfège I | |
| or 57-185 | Advanced Solfège I | |
| 57-173 | Survey of Western Music History (co-requisite: 57-188) | 9 |
| 57-188 | Repertoire and Listening for Musicians | 1 |
| 18-090 | Twisted Signals: Multimedia Processing for the Arts | 10 |
| 57-911 | Music Since 1945 | 9 |
| 57-616 | Independent Study in Sound Studies | 9 |

Choose 52 units from:

| | | |
|-----------|--|----|
| 57-153 | Harmony II | 9 |
| or 57-150 | Basic Harmony II | |
| 57-182 | Solfège II | 3 |
| or 57-186 | Advanced Solfège II | |
| 15-104 | Introduction to Computing for Creative Practice | 10 |
| 15-322 | Introduction to Computer Music (prerequisite: 15-112) | 9 |
| 33-114 | Physics of Musical Sound | 9 |
| 57-337 | Sound Recording | 6 |
| 57-338 | Sound Editing and Mastering | 6 |
| 57-343 | Music, Technology, and Culture | 9 |
| 57-344 | Experimental Sound Synthesis | 9 |
| 57-347 | Electronic and Computer Music (prerequisite: 57-101 or 57-171) | 6 |
| 57-358 | Introduction to Electronic Music (with instructor permission as space allows) | 9 |
| 57-421 | Exploded Ensemble | 6 |
| 57-438 | Multitrack Recording | 9 |
| 57-478 | Survey of Historical Recording | 6 |
| 60-131 | Foundations: Sculpture | 10 |

Note: Students completing an IDEaTe minor may double-count up to two of the IDEaTe minor courses towards the Sound Theory & Practice concentration.

Academic Policies

Professional and Community Standards

As a condition of enrollment BXA, and as a student in the College of Fine Arts, we expect you to positively contribute to the community in order to fully engage in the intellectual life at CFA. Classrooms, studios, rehearsal and performance spaces, exhibition venues and off-campus curricular destinations are safe spaces for expression and self-identification. Students are expected to treat everyone with respect, regardless of race, country of origin, gender identity and expression, sexual orientation, disability, physical appearance, age, religion, political affiliation or marital status. Lack of respect and harassment includes offensive comments related to any protected personal characteristic, deliberate intimidation, sustained disruption of speech, inappropriate physical contact and unwelcome sexual attention. Violations of this agreement are subject to a response to be determined by the BXA Director and CFA Associate Deans.

Academic Standards and Actions

The College of Fine Arts reviews every CFA student's academic performance and progress towards graduation at the end of each semester. If a student's academic record falls below the standards outlined in their student handbook, they receive an academic action. These actions are designed to notify the student of specific academic and graduation requirements, outline goals for completion, and identify avenues of support to help them succeed.

A student who is not making satisfactory progress toward meeting course standards, or toward completing graduation requirements in their declared degree path, will receive an academic action. Each academic action will be reviewed by the relevant school's appointed reviewers and then confirmed by the CFA Academic Advisory Committee, which makes the final decision. The CFA Dean's office will disseminate the academic action letters directly to the students and their advisors via their CMU email.

Actions are assigned based on the most recent semester under review but include a cumulative review of a student's performance to date. The actions listed below may be given out of sequence, if a student meets the listed criteria.

Incomplete grades will be conditionally actioned by the default grades until the student completes the missing coursework. If the student does not complete their missing coursework by the faculty deadline agreed upon, their default grade and action will become permanent.

In order to support academic success, a student placed on an escalated academic action (probation and final probation) is not permitted to overload, undertake independent studies, or study abroad until they return to good standing. (See school/program handbook for specifics.)

Warning

A Warning notifies the student of unsatisfactory performance and suggests that the student take steps to determine and correct the cause of the difficulty. Warnings are issued when one or more of the listed criteria are met within the semester under review:

- Receiving an R, D, or N in one elective or general education course;
- Failure to complete the semester's coursework as required by the student's major curriculum (one course);
- Failure to earn the minimum 2.00 quality point average.

If the student meets new actionable criteria in the following semesters, they may be assigned an escalated academic action.

Probation

Probation notifies the student of severe and/or continuous performance issues and suggests that the student take immediate steps to correct the cause of the difficulty. A previous action is not required. A student will be placed on Probation for failure to meet the academic and professional standards of their program including:

- Receiving one or more R, D, N, or W grade(s) in a required major course(s);
- Receiving two or more R, D, N, or W grades in elective or general education courses (either during one semester or over two semesters);
- Failure to complete the semester's coursework as required by the student's major curriculum (either two or more courses during one semester or over multiple semesters);
- Failure to earn the minimum 2.00 quality point average.

In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may continue on Probation or be assigned a successive academic action.

Students who are on academic Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to school/program handbooks for specific information.

Final Probation

A student will be placed on Final Probation for continued poor performance, or for continued failure to meet the requirements of their declared degree path, as outlined under the previous section on Probation. At least one previous action (warning and/or probation) must have been assigned prior to assigning final probation.

- Receiving multiple R, D, N, or W grades in a required major course(s) for two or more semesters;

- Receiving three or more R, D, N, or W grades in elective or general education courses over multiple semesters;
- Failure to complete the semester's coursework as required by the student's major curriculum (three or more semesters);
- Continued failure to earn the minimum 2.00 quality point average (two or more semesters).

In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may continue on Final Probation or be assigned a successive academic action.

Students who are on academic Final Probation have restrictions from participating in some school, college, and university activities, including eligibility for study abroad or school awards. Refer to school/program handbooks for specific information.

Academic Suspension

All University Suspensions are a required, temporary leave from the university. This document covers **Academic Suspension** from the University. (For more information on *Disciplinary Suspension* or *Administrative Suspension* visit the *student life* sections on the university website: <https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html>).

An Academic Suspension is intended to allow the student time to address or rectify any issues impeding or affecting their performance and progress towards meeting the academic standards of their declared degree path. The student is required to temporarily withdraw from the university for a specific period as defined in their suspension letter. Return from suspension is also subject to the conditions specified in the suspension letter and approval of the CFA Dean's office. At least two previous actions must have been assigned prior to assigning Academic Suspension.

A student will be placed on Academic Suspension for:

- Continued history of poor academic performance (three or more semesters);
- Continued lack of progress towards their declared degree (three or more semesters);
- Continued failure to meet the requirements of their declared degree path for continuing in the program; (three or more semesters)
- Failure to earn the minimum 2.00 quality point average. (three or more semesters)

A student returning from an Academic Suspension will be placed on Probation for the semester. In order to return to good standing, a student must:

- Receive a C or better in all courses in the next semester;
- Complete required courses within the defined school timeline;
- Have a minimum of 2.00 QPA.

If the student does not meet these standards, they may be considered for an Academic Drop.

A student who has been suspended from the university is required to leave the campus, including residence halls and fraternity/sorority houses, within a maximum of two days after the action and to remain off the campus for the duration of the time specified in the suspension letter. In addition, the student may not:

- register for courses at Carnegie Mellon
- attend classes
- live in residence halls or fraternity/sorority housing
- use campus facilities, including athletic facilities, library and computer clusters
- participate in student activities
- be members of student organizations
- have student jobs

(Note: students on academic suspension may still be eligible for a summer campus job if they accepted the job before they were suspended.) Go to the university policy webpage on student life for more information on a University Suspension: <https://www.cmu.edu/policies/student-and-student-life/suspension-required-withdrawal-policy.html>

Academic Drop

Students receive an Academic Drop from their School only when the student's academic progress is insufficient to warrant continuing in the current professional field of study. This action terminates the student's

enrollment in their current School/Program but is not intended to prejudice admission to another academic program within Carnegie Mellon University, or to another institution. Once a student receives an Academic Drop they may choose to:

1. Transfer to another CMU Department or School. Noting that the student must successfully transfer *prior* to resuming study at Carnegie Mellon.
2. Withdraw from Carnegie Mellon University. A link to the application for Withdrawal/Leave of Absence form is embedded with the letter notifying the student of this academic action, and is also available at <https://www.cmu.edu/hub> (<https://www.cmu.edu/hub/>).

Appeal of Academic Action

Students have the right to appeal academic actions. If a student believes an academic action is inconsistent with BXA policies or merits additional review, a student should submit a formal written appeal, as specified in the initial academic action letter, to the assistant/associate deans listed below, with a copy to the deans of both CFA and their academic college. Appeals should include all relevant materials to substantiate their case and support their concerns.

A student may appeal to the relevant assistant/associate deans within seven days from the date of their academic action letter. All appeals should be in written form, under three pages in length (not including appendices) and authored by the student.

BCSA Appeals should be addressed to:

Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts

Guy Billeloch, Associate Dean for Undergraduate Education, Computer Science Department

BESA Appeals should be addressed to:

Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts

Conrad Zapanta, Associate Dean for Undergraduate Studies, College of Engineering

BHA Appeals should be addressed to:

Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts

Kelli Maxwell, Associate Dean of Student Success, Dietrich College of Humanities and Social Sciences

BSA Appeals should be addressed to:

Kristen Letts Kovak, Senior Associate Dean for Academics, College of Fine Arts

Maggie Braun, Associate Dean for Undergraduate Affairs, Mellon College of Science

If, after carrying out the steps of the process described above, the student believes that the matter has not been adequately resolved, or if no decision has been rendered by the appropriate date, the student may appeal at the university level. To appeal at the university level, the student must present copies of all previously submitted documents and a formal letter of appeal to the provost. The provost or another designated university officer will respond in writing with a final resolution, including the basis for it, within thirty (30) days when possible.

Disabilities

Students with a learning disability or a physical disability are encouraged to email access@andrew.cmu.edu. The circumstances will remain confidential to the extent desired. The university has a formal procedure for documenting disabilities, notifying advisors and faculty, and making arrangements to utilize university resources in support of expressed needs, but will take no action until contacted by the student. The BXA academic advisors will work with the student to coordinate assistance. Please note that requests for accommodations are not retroactive; you must ask that accommodation requests be put in place before you anticipate needing them.

Grading Policies

University grading policies may vary depending on the particular school/department. Please consult the Undergraduate Academic Regulations (<http://coursecatalog.web.cmu.edu/servicesandoptions/undergraduateacademicregulations/>).

Intercollege Deans' List

Students who earn 36 graded units (no "pass/no pass" grades) with a grade point average of 3.5 or higher, no "incompletes" and "no grades" qualify

for BCSA, BESA, BHA or BSA Deans' List. The BX A Intercollege Deans' List Honors are posted online each semester.

Intercollege Honors

BX A students who successfully complete a BX A Capstone Project under the guidance of a faculty member will graduate with BCSA, BESA, BHA, BSA or EA Intercollege Honors if all of the following conditions are met:

- grade of "A" achieved in 62-401 and 62-402;
- overall QPA of 3.25 or higher;
- research results presented at Meeting of the Minds Undergraduate Research Symposium.

As a citizen of two colleges, a BX A student also has the opportunity to graduate with CFA College Honors, DC College Honors, ENG College Honors, MCS College Honors and SCS College Honors. These particular honors are defined by each college. BX A students will receive honors color cords during Commencement Weekend.

University Honors

Students who graduate with an overall QPA of 3.5 or higher will graduate with University Honors. Students will receive an honors medallion during Commencement Weekend.

Internal Transfer/Additional Major Process

For current Carnegie Mellon students who wish to apply to a BX A program, an internal transfer and additional major (EA) application process takes place in both the fall and spring semester. Applications are available online and are reviewed by a committee of BCSA, BESA, BHA, BSA and EA advisors in October and in March. However, certain concentrations consider applications only once a year; please consult with a BX A advisor for guidance on scheduling your application.

All students applying for internal transfer should meet with their current advisor, a BX A advisor and an advisor in their target area, as well as take preliminary coursework in their target area and complete their first semester before applying. For all concentrations, there are required courses that must be taken before an application will be considered; please consult with a BX A advisor for guidance on scheduling these courses.

Current BX A students who wish to change their BX A program (e.g. BHA to BCSA) or change their CFA concentration (e.g. BHA architecture to BHA art) or delineated options within CFA concentrations (e.g. music performance to music composition) must apply for that change through the internal transfer process. Current BESA, BHA and BSA students who wish to change their academic college concentration after declaring (e.g. BHA creative writing to BHA psychology, BSA physics to BSA mathematical sciences) or delineated options within their academic college concentration (e.g. BESA chemical engineering to BESA mechanical engineering) after declaring must submit a new BESA ENG/BHA DC/BSA MCS Concentration Declaration form for approval of that change. Current BX A students seeking internal transfer out of BX A into another college program must apply and meet entry requirements to that program. Students who do not remain in BCSA can only return to their original major.

Study Abroad

Studying abroad is encouraged to broaden BX A students' interdisciplinary experiences through traditional and non-traditional study abroad, from coursework and artistic studios to for-credit internships, volunteer service and research opportunities.

Courses taken while studying abroad may count toward your BX A concentration requirements, your general education requirements or your free electives. Studying abroad should not delay your graduation, as long as you work with your study abroad advisor and your BX A advisor to plan the most appropriate courses.

The timing and length of program are important considerations while planning. Due to required BX A coursework, students should avoid studying abroad in their last three semesters (junior spring, senior fall/spring). Spending an entire year abroad is not typically possible for BX A students without intending to take an additional semester at Carnegie Mellon. Many students study abroad during the spring of their sophomore year or the fall semester of their junior year, as well during the summer, and over winter and spring breaks. Talk to your BX A academic advisor early in your academic career to identify the best time for study abroad.

When studying abroad, students are still enrolled at Carnegie Mellon. A student never takes a leave of absence to study abroad. Prior to studying

abroad, all students must attend a required pre-departure orientation offered by the Office of International Education (OIE).

Students must also complete a Study Abroad Transfer Credit (SATC) form prior to departure for study abroad, which must be signed after completion by the BX A advisor. The SATC will guarantee transfer credit for courses taken abroad, and is filled out by the corresponding departments to the coursework being transferred. Unlike regular transfer credit, there is no limit to the number of courses transferable from study abroad, but there may exist stricter limits on the use of coursework to fulfill concentration or general education requirements.

Students will receive credit for courses for which they receive a grade of "C" or better. However, grades received abroad do not count toward a student's Carnegie Mellon University QPA.

Transfer Credit

Once a BX A student enrolls at Carnegie Mellon University as a degree candidate, they may transfer a maximum of five courses from another institution (excepting official study abroad programs through the CMU Office of International Education) for credit towards their BX A degree. This applies to courses taken at other institutions in the United States, as well as courses taken internationally in the student's home country.

Individual departments may impose stricter limits regarding the number or type of courses students propose to take elsewhere to fulfill requirements. Some departments may not accept transfer credit from online courses.

Students must have prior approval to transfer courses from their BX A advisor, as well as concentration advisors, to use coursework towards requirements. To receive permission, students must provide course information (syllabi) to the corresponding department for evaluation of appropriate credit. When the course is finished, official transcripts must be sent to Carnegie Mellon University before credit will be recorded.

Transfer courses must be taken for a letter grade and students must earn a C (2.00) or above (B or above at a community college). Transfer credit is not factored into a student's CMU QPA.

The following courses must be taken at CMU and cannot be transferred in:

- First-Year Writing Requirement Course (76-101, 76-102, 76-106/7/8)
- Humanities (79-104, 79-145, 79-189)
- 36-200: Statistical Reasoning (AP credit only)
- 99-101: Computing @ Carnegie Mellon

Students currently on university suspension are permitted to take no more than three courses per semester at another institution and no more than a total of five courses.

Withdrawal or Leave of Absence

A student who decides to leave the university must meet with their BX A advisor and complete a Withdrawal or Leave of Absence form. Withdrawal means leaving the university with no intention of returning. Leave of Absence means temporarily leaving the university with a stated intention to return. A withdrawal or leave of absence from the university at any time up to and including the last day of classes (excluding the final examination period), means that grades of W will be recorded for all classes for the semester. Financial responsibility for the semester is dependent upon the date of and the reasons for filing the form. Questions about financial responsibility should be directed to the HUB.

A leave of absence may be voluntary or involuntary. If the leave is voluntary, the student may return any time within four years following the beginning of the leave by filing an Application for Return from Leave of Absence form. If the leave is involuntary, that is, required for academic or disciplinary reasons, the conditions for return will be stated.

BXA Intercollege Program Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

52-190 BXA Seminar I: Building the Wunderkammer

Spring: 4.5 units

BXA Seminar I considers how knowledge is represented across different modes of media: what language, what symbols, what logic guides knowledge acquisition and expression in your varied disciplines? Students engage with theoretical and practical readings from across disciplines, with particular emphasis on interpretive theory. Weekly readings in aesthetic and critical theory introduce students to a particular vocabulary of analysis, practiced in class discussion and written responses. Students will conceive, research, produce and present a creative final project at the end of the course.

52-291 BXA Seminar II: Transferring Knowledge

Spring: 4.5 units

BXA Seminar II considers how interdisciplinary work can be produced, analyzed, justified and most importantly contextualized. By taking a deep dive into a single object or text, we'll explore how context situates the creator, the audience, and their relationship. At the end of the course, students will have a better understanding of how disciplinary methods establish context, and they'll be able to use this understanding to help guide their academic choices.

52-292 BXA Student Advisory Council

Intermittent: 3 units

This course will provide opportunities for students to promote and refine the mission of the BXA programs. Students will develop and practice leadership skills, including collaboration, communication, and project management. Students will be responsible for planning and running BXA student events, including info sessions, social hours, skills workshops, and alumni events. Students are encouraged to think about how to engage other interdisciplinary scholars and artists as well as how to present their own work and programs to the larger university community.

52-390 BXA Undergraduate Research Project

All Semesters

The BXA Undergraduate Research Project is for BXA students who want to work on a self-designed project with the one-to-one guidance of a faculty advisor. The project should be interdisciplinary in nature, and can be a scholarly and/or creative endeavor. The project may take the form of a written thesis, a compilation of creative works, an outreach project, etc. The project topic must be pre-approved by the faculty member who agrees to supervise the project and assign a letter grade for the course. Projects are to be completed in one semester, may be worth 3, 6, 9, or 12 units of academic credit, and cannot be taken concurrently with the BXA Capstone Project during the senior year. To register, students must submit an "Undergraduate Research Project Proposal Form" signed by both the student and the faculty advisor, along with a proposal, to their BXA academic advisor.

52-392 BXA Seminar III: Deconstructing Disciplines

Spring: 9 units

BXA Seminar III is in preparation for the BXA Capstone Project and/or other senior research projects (Dietrich/MCS/SCS thesis, or CFA senior studio work). The seminar will engage BXA juniors in a brief examination of the structures of disciplinary knowledge, interdisciplinary approaches, and the components of research, with production of original work as the primary class requirement. The course is designed with maximum flexibility for various schedule conflicts and attendance; check course syllabus for meeting times and options. Coursework includes short readings and self-assessment exercises, participation in seminar discussions, preparation of the Junior Portfolio and professional documents (CV), and the production of new research or creative works. These can take one of three forms: 1) a small proof of concept object 2) the initiation of one stage of larger research plans or 3) a complete Capstone proposal. Any of these may be the basis of the student's eventual Capstone or other senior work. The requirements for this semester also include a short 5 page literature review about the student's topic, inclusion of work during the BXA Kaleidoscope show (last week of April), and a class research presentation showcase held during the final exam period.

52-401 BXA Seminar IV: Capstone Project Research

Fall and Spring

The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BC SA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students), or CFA concentration and engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Project Research (9 units), which meets weekly to discuss strategies for managing research, planning the project, and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography, and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Project Production (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May. Students will only be enrolled for 18 units when they are unable to complete a two-semester sequence and need to gain special permission by the BXA Director/Academic Advisor. The BXA Capstone sequence is for students in their last two semesters before graduation.

52-402 BXA Seminar V: Capstone Project Production

Fall and Spring: 9 units

The BXA Capstone gives BXA students the opportunity to demonstrate the extent of their interdisciplinary work over the course of their academic career. The Capstone should include elements that span the student's CFA and SCS concentrations (for BC SA students), CFA and DC concentrations (for BHA students), CFA and MCS concentrations (for BSA students), or CFA concentration and engineering major (for EA additional major students). The project can be either a scholarly or creative endeavor, and may take one of many possible forms (e.g., a written thesis, a compilation of creative work or works, an experiment and report, a computer program or animation, etc.). The BXA Capstone sequence covers both semesters of a student's senior year. In the fall, students are enrolled in 52-401 BXA Seminar IV: Capstone Project Research (9 units), which meets weekly to discuss strategies for managing research, planning the project, and larger theoretical issues related to interdisciplinary work. At the end of the fall course, students will have produced a Capstone Project proposal, an annotated bibliography, and multiple versions of their project pitch. In the spring, students enroll in 52-402 BXA Seminar: Capstone Project Production (9 units), which has no required classroom time. Instead, students spend the semester doing the research and foundational work necessary for the project, as well as meeting with their faculty and BXA advisors as they create their Capstone Project and prepare to present it at the annual Meeting of the Minds Undergraduate Research Symposium held each May. The BXA Capstone sequence is for students in their last two semesters before graduation.

52-590 BXA Internship

All Semesters

An internship is a supervised professional work experience with clear links to a student's academic goals. BXA students may choose to complete a BXA Internship for elective credit with appropriate individuals or organizations within or outside of Carnegie Mellon University. Junior and senior BXA students in good academic standing are eligible to receive academic credit for one internship. Grading is pass/no pass only. Prior to enrolling in an internship, the student must have a "BXA Internship Agreement Form" signed by their site supervisor and approved by their BXA academic advisor.

Carnegie Mellon University-Wide Studies Courses

About Course Numbers:

Each Carnegie Mellon course number begins with a two-digit prefix that designates the department offering the course (i.e., 76-xxx courses are offered by the Department of English). Although each department maintains its own course numbering practices, typically, the first digit after the prefix indicates the class level: xx-1xx courses are freshmen-level, xx-2xx courses are sophomore level, etc. Depending on the department, xx-6xx courses may be either undergraduate senior-level or graduate-level, and xx-7xx courses and higher are graduate-level. Consult the Schedule of Classes (<https://enr-apps.as.cmu.edu/open/SOC/SOCServlet/>) each semester for course offerings and for any necessary pre-requisites or co-requisites.

99-101 Computing @ Carnegie Mellon

Fall and Spring: 3 units

Computing@Carnegie Mellon (C@CM) is a 3-unit, pass/fail mini course that will help you develop foundational computing and information literacy skills, focusing on the tools and technologies that are specific to Carnegie Mellon so you can be successful in your other academic courses. All undergraduate students are required to take the course. C@CM is offered in a hybrid format through the Open Learning Initiative's (OLI) online course environment; meaning that you'll complete your coursework online and attend a face-to-face recitation session for review and supplemental instruction.

Course Website: <http://www.cmu.edu/c-cm/>

99-129 DC Grand Challenge First-Year Seminar: Unreality: Immersive and Spatial Media

Intermittent: 9 units

Virtual news stories and game worlds are accessible by putting on cardboard goggles, theme parks are engineered to provide convincing multisensory experiences, and workforces are reliant on augmented views of factory floors. Immersive and spatial media constitute a suite of emerging technologies that offer the opportunity to expand arts, entertainment, science, design, commercial enterprises and countless other domains in ways that were previously limited to science fiction. The potential for augmented reality to disrupt our current technological ecosystem is tremendous. Many of these technologies are now 50 years old and just starting to enter the commercial realm. As immersive experiences and augmented realities become more integrated into our work and leisure, do we need to worry about the ways that unreality affect our experiences of reality, or our interactions with each other? How do we know that we can trust our senses to tell us what is real? How do we begin to grapple with the ethical, cultural, social, technological, and regulatory implications of this shift?

99-153 Mindful Living

Fall and Spring: 3 units

The goal of this course is to increase students internal resources for meeting stress through mindfulness-based meditation training. Each week, students will be trained in formal mindfulness meditation practices and asked to meditate at home with the help of brief guided meditation recordings. Students will also be given weekly informal mindfulness practice suggestions to help them translate the skills of formal meditation practice into daily life. Class meetings will give students the weekly opportunity for reflection, discussion, and questions based on their experience of formal and informal practice assignments.

99-190 Managing Stress, Restoring Harmony

Fall: 6 units

The course is designed to explore the subject of stress and how it can best be managed to achieve optimal health and wellbeing. Topics addressed will include: the environmental, mental and emotional components of stress, factors that affect the experience of stress, how stress contributes to illness, and an overview of various stress management techniques. Several lectures will be supported by Carnegie Mellon faculty and staff.

99-194 Intimate Relationships & Sexual Health

Spring: 6 units

This course will explore the expression of human relationships and sexuality. Emphasis will be placed on college health and the social, cultural and health factors that affect relational interactions. This course is designed to assist students with improved functioning in personal relationships, provide information to take care of their sexual health and help them acquire skills to make decisions now and in the future. Topic areas will include relationships, sexual behavior, sexual health and interpersonal skills. Academic support will be provided by campus and community partners.

99-250 Seminar for Peer Mentors

Fall and Spring: 1 unit

SPECIAL PERMISSION REQUIRED: YES The purpose of this training course is to provide undergraduates with the knowledge, skills, and experience necessary to become effective Peer Tutors. Throughout the course, students will be exposed to the mission and goals of Academic Development and the Peer Tutoring Program. The class lasts approximately nine weeks and is generally offered in the spring term from February through April. The course explores the roles and responsibilities of the tutor while offering insights into effective tutoring strategies through interactive discussion and role plays. In addition, trainees work hands-on with experienced tutors to troubleshoot potential problems and situations. Students will gain experience in group dynamics, communication skills, study strategies, referral resources, leadership, and creating a supportive learning environment. Teaching practice is an integral part of the training program. Students must complete an application in person or electronically at course URL and then be interviewed by the instructor(s) to determine if the student possesses the basic qualifications.

Course Website: <http://www.cmu.edu/acadev/studentjobs/>

99-262 ADDvocate: Anti-Discrimination Dialogue for Social Justice

Fall and Spring: 6 units

The aim of this multidisciplinary course is to establish a firm, education-based understanding of Diversity, Equity, and Inclusion topics in Pittsburgh, Qatar and Worldwide to enhance their classroom and university experience. Through a series of lectures by subject experts, this course aims to educate and raise consciousness of discrimination, racism and bias in the real world. This course will also highlight strategies to become an active bystander and advocate for fair treatment in all our communities.

99-264 Introduction to Life Design

Fall and Spring: 3 units

What do you want to be when you grow up? is a dysfunctional question that is asked by society to every child. The nature of this question implies individuals should have a single goal that they should desire to reach and happiness/success will be achieved when this goal is reached. Instead, Introduction to Life Design asks individuals to explore what they want to grow into as life unfolds. Students in this course will identify what work and life mean to them, explore how their social identities influence how they engage with the world, ideate future possibilities, and learn how to explore those possibilities by prototyping experiences. This class is not for individuals looking for help in securing a job or internship opportunity. This class is for those who want to learn how to create and navigate a life of meaning.

99-270 Summer Undergraduate Research Apprenticeship

Summer

This course consists of student participation in projects focused on undergraduate research or creative inquiry under the direction of a Carnegie Mellon faculty member. Tenure track, teaching track, research track, librarian track, and special faculty may serve as SURA mentors. The subject of the inquiry, the number of units, and the criteria for grading are to be determined by the student and the faculty mentor. This agreement should be formalized in a one-page apprenticeship verification form that includes documented approval from the faculty mentor with a copy to be submitted to the Undergraduate Research Office. The students are responsible for finding a faculty member who is willing and able to supervise them on campus over the summer. In addition to the research experience, course requirements include a series of workshop sessions over the course of the summer that will introduce students to the basics of research design. Students will also be expected to present and/or attend the campus-wide undergraduate research symposium, Meeting of the Minds, in May of the following year. Students may register for a maximum of nine units with work to be completed over an eight-week period during the summer all term.

99-352 IDEaTe: Soft Fabrication Skills

Fall and Spring: 1 unit

PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 16, Sep 23, Sep 30. Textiles are a ubiquitous part of our everyday tactile experience. This workshop series aims to introduce textile techniques to participants with diverse backgrounds across the CMU campus. The fabrication skills and concepts that will be covered in this course will be taught from an interdisciplinary approach to merge practices in arts and technology. Students will learn methods of working with fabric such as hand and machine sewing, felting and knitting, along with merging aspects of digital fabrication and physical computing using flexible materials. Through discussions and demos, participants will have the opportunity to explore new methods of fabrication to integrate into their own practice.

Course Website: <https://courses.ideate.cmu.edu/99-352> (<https://courses.ideate.cmu.edu/99-352/>)

99-353 IDEaTe: Design Essentials for Laser Cutting

Fall and Spring: 1 unit

PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 23, Sep 30, Oct 7. The specific meeting dates for the A2 section of this micro course are Oct 29, Nov 5, Nov 12. This mini course is designed to get students ready to use a lasercutter. We will cover essential design considerations unique to lasercutting, material tolerances, available methods of assembly and finishing techniques, but the bulk of the class time is spent hands-on learning to design and create a lasercutter ready vector file. The primary software we use is Adobe Illustrator, with some time also spent in Photoshop for learning how to integrate raster images like photos and drawings into lasercut objects. Over the three classes, we will also discuss 2D, 2.5D and 3D design basics, how to create tight joinery by understanding kerf, how to improve your photo engravings, and when switching software will save you a lot of time. Students who complete this course will be able to use the IDEaTe facility's laser cutters on their own for future course work or personal projects.

Course Website: <https://courses.ideate.cmu.edu/99-353> (<https://courses.ideate.cmu.edu/99-353/>)

99-355 IDEaTe: Introduction to Arduino

Fall and Spring: 1 unit

PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 22, Sep 29, Oct 6. The specific meeting dates for the A2 section of this micro course are Oct 29, Nov 5, Nov 12. This workshop aims to demystify the Arduino microcontroller through hands-on work in the lab creating simple machines with embodied behaviors. The Arduino is a versatile resource for physical projects for students in all disciplines. This course brings students over the beginner's threshold to a basic understanding of the use, terminology, and potential of the Arduino. The skills and concepts taught in this course are presented from an interdisciplinary approach which merges practices in arts and technology. The first portion will teach the essential skills for creating a simple sensor-driven physical computing system, and the second portion will reinforce those skills by making a simple interactive project. The course has no technical prerequisites, although uses a little bit of algebra-level math. Undergraduate students, graduate students, faculty and staff interested in learning new skills in an interdisciplinary environment are welcome!

Course Website: <http://courses.ideate.cmu.edu/99-355> (<http://courses.ideate.cmu.edu/99-355/>)

99-356 IDEaTe: Digital Media Literacies: Great World Challenge

Fall and Spring: 9 units

This course introduces students to new media for ethically finding, evaluating, producing and sharing artistic and scholarly innovations. It allows students the opportunity to gain practice with and exposure to tools, technologies and processes which support data analysis, visualization, communication, presentation and sharing through a variety of emerging and established dissemination channels. Students who excel in the course may be further supported in identifying and pursuing appropriate publication outlets for their research. The course will be of particular interest to students planning to engage in further undergraduate research opportunities.

99-357 IDEaTe: Pragmatic Photography

Fall and Spring: 1 unit

PLEASE NOTE: The specific meeting dates for the A1 section of this micro course are Sep 24, Oct 1. The specific meeting dates for the A2 section of this micro course are Oct 28, Nov 4. Pragmatic Photography is a digital imaging course for the non-photographer. A tech-first approach provides a strong grounding in the core concepts and techniques of image-based media. This course will enable students to create photographs for project documentation. This class will not require special cameras or software; students will use commonly-available photo-editing software to create images using DSLRs, point and click cameras, or their cell phones. The course focuses on general principles that apply across different equipment and software.

99-361 IDEaTe Portal

Spring: 9 units

Full descriptions of each section topic are available at <https://courses.ideate.cmu.edu/99-361>. IDEaTe Portal courses introduce students to key aspects of critical, creative, and technical practice and prepare them to engage in productive interdisciplinary Collaborative Studio coursework in IDEaTe minor areas. Section A: Inflatables students will focus on the design, fabrication, and creative applications of sculptural and inflatable forms created from soft materials. Section B: Intelligent Environments highlights the motivation and requirements for intelligent environments and components that could be used to add functionality to existing environments.

Course Website: <https://courses.ideate.cmu.edu/99-361> (<https://courses.ideate.cmu.edu/99-361/>)

99-362 IDEaTe: Intelligent Learning Spaces

Spring: 9 units

Intelligent Learning Spaces explores the interactions between human learning and the spaces in which learning occurs. In this project-based course, students discuss, analyze, define, and apply theory from education, architecture and the arts to their project work. Students investigate precedents and existing experiences to create their own learning manifestos and designs. Imagination, in-class participation, speculation, empathy and 360-degree awareness are key components of this class. Students work on scaffolded projects that build on their knowledge to showcase their intentions and creativity, reacting to a variety of contexts relevant to learning. Students have opportunities to develop creative inquiry skills and apply critical perspectives through project-based work that requires experimentations, hands-on learning, reflection, and documentation.

99-363 IDEaTe: Spatial Storytelling

Spring: 6 units

Spatial Storytelling promotes the use of digital storytelling methods and methodologies across disciplinary topics. In this Spring mini, students are guided through the process from identifying a research problem, collecting data from diverse sources, learning specific geospatial mapping tools, and finally crafting narrative. They will work with spatial information (geospatial data) to build complex multimodal narratives around social issues. By the end of this course, students will know: what are spatial data, how to find and identify different types of spatial data, how to create a story based on data, and how to analyze data in geospatial software. Students will be able to develop constructive critique and data literacy skills to critically review peer work across disciplinary topics. Using competencies gained over the semester, students will create an online interactive narrative and present it to the broader community.

99-382 Technology, Humanity, and Social Justice: Environment

Fall: 3 units

As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2022, the focus will be on humanity's use of technology and the disparate impacts on and benefits to the environment and varying groups of people. This will include discussion around the material, environmental, and health costs of extracting materials necessary to technology development and production as well as the waste created by the consumption habits initiated by global reliance on technology. It will also include a discussion of technology's role in advancing sustainability. Added Note: The course will occur on Friday, Nov. 4th, Saturday, Nov. 5th, and Sunday, Nov. 6th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

99-384 Technology, Humanity, and Social Justice: Health

Intermittent: 3 units

As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2023, the focus will be on the impact technology has on human health. This will include a discussion about technology's impact on human interactions, including mental health amid a pandemic and changing working conditions. It will also include a focus on the accessibility and disparities on health care's increased reliance on technology across the globe as well as the transition to digitizing health records and the dangers this creates in relation to privacy. Added Note: The course will occur on Friday, Oct. 27th, Saturday, Oct. 28th, and Sunday, Oct. 29th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

99-409 Summer Research

Summer: 1 unit

This course allows undergraduate students from all fields to participate in research (including artistic/creative inquiry) under the direction of a Carnegie Mellon faculty member. Tenure track, teaching track, research track, librarian track, and special faculty may serve as research supervisors. Students should have previously participated in summer research via the Summer Undergraduate Research Apprenticeship and/or the Summer Undergraduate Research Fellowship before enrolling in 99-409 (students who are unsure of whether 99-409 is appropriate for them should consult with the Undergraduate Research Office). Students will need to complete a supervisor agreement form to be eligible for participation in this tuition-free 1-unit course. Students are responsible for finding research supervisors. In addition to the summer research with the faculty member, students will be expected to write a brief (one- to two-page) research report about their summer work. This course is not eligible for CPT for international students; please contact the Office for International Education for more information regarding CPT.

99-520 Collaborative Research through Projects

Summer

This course has students engage in experiential learning via interdisciplinary projects around a variety of topics determined by each instructor. Students should review the lengthier descriptions for each section posted on the Office of the Vice Provost website under the Academic Resources tab to gain more knowledge of the projects and pre-requisites. <https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyeIk/edit?usp=sharing>

Course Website: <https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyeIk/edit?usp=sharing> (<https://docs.google.com/document/d/1JRPqsB15OBd-gWgrCuUXAqCnE7JApt4HmLehtNHyeIk/edit?usp=sharing>)

99-530 Senior Preparation Seminar

Fall and Spring: 6 units

This mini course provides graduating seniors a chance to reflect on their experiences as students at Carnegie Mellon; intellectually, socially and as leaders in this community. In addition to its reflective component, the course will also look at how to prepare for upcoming transitions into post college roles and responsibilities. The course explores intrapersonal, interpersonal, and external factors at play for recent graduates.

99-784 Technology, Humanity, and Social Justice: Health

Intermittent: 3 units

As humans rely more and more on electronic devices to support their everyday activities, there are ever present warnings about the impacts such reliance has on human autonomy ranging from who owns and controls information networks, the inequitable impact of technology consumption on peoples and places, varying accessibility of technology around the globe, and the promises and limitations of technology in improving human health. By engaging in technology as a lens, this sequence of weekend micro-courses encourages students to examine technology as a system disproportionately impacting humanity by enabling and constraining human rights of groups of people around the globe. With a multi-disciplinary focus, the course invites researchers and practitioners from the University of Pittsburgh, Carnegie Mellon, and relevant fields more broadly. In Fall 2023, the focus will be on the impact technology has on human health. This will include a discussion about technology's impact on human interactions, including mental health amid a pandemic and changing working conditions. It will also include a focus on the accessibility and disparities on health care's increased reliance on technology across the globe as well as the transition to digitizing health records and the dangers this creates in relation to privacy. Added Note: The course will occur on Friday, Oct. 27th, Saturday, Oct. 28th, and Sunday, Oct. 29th. Engagement in the course should be synchronous; accommodations for those in significant time zone differences will be provided to allow enrollment and completion of all elements of the weekend. If a student is interested in the course but unable to engage in the course dates, please reach out to Korryn Mozisek (kmozisek@andrew.cmu.edu).

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