ISAAC NEWTON (January 4, 1643 – March 31, 1727)

by HEINZ KLAUS STRICK, Germany

ISAAC NEWTON was born on Christmas day in the year 1642 in the hamlet of Woolsthorpe-by-Colsterworth, Lincolnshire, England – if one follows the Julian calendar, which was still in force in England at the time. His father, a well-to-do farmer, died three months before the birth of his son. When his mother remarried in 1645, the boy ISAAC was given to his grandmother to be raised. He returned to his again-widowed mother with her three additional children in 1653. As the oldest son of the by this time well-off widow, it was thought that he would take over the management of the family's estate, but Isaac showed not a whit of interest in, or talent for, such things.

His uncle saw to it that ISAAC attended *King's School*, in neighbouring Grantham. He began in about 1654, but left in 1659 for a while (in a report, he was cited for being lazy and inattentive). He returned to *King's School*, and in 1661 enrolled in *Trinity College*, Cambridge. In addition to ARISTOTLE's philosophy, which formed the center of the curriculum, NEWTON became acquainted with the philosophical writings or RENÉ DESCARTES and works on physics by JOHANNES KEPLER and GALILEO GALILEI.

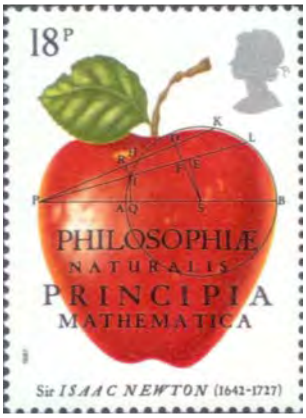
In the autumn of 1663, he stumbled on a book on astrology and one on trigonometry and realized in both cases that he needed to obtain a deeper understanding of geometry. He therefore decided to study EUCLID's *Elements*. After that came a self-study of DESCARTES' *La Géométrie*, FRANÇOIS VIÈTE's *L'algèbre Nouvelle* from the year 1646, and the algebraic writings of JOHN WALLIS, in which WALLIS describes the calculation of the areas under a parabola and under a hyperbola.

His principal method involved the *indivisibles* of BONAVENTURA CAVALIERI, which are infinitely thin entities *smaller than any arbitrarily given positive value.* In his copy of WALLIS, NEWTON wrote, *that may be how Wallis does it, but this is how I do it. . . .*

The greatest influence on the student NEWTON, however, had ISAAC BARROW, who in 1663 was appointed to the newly created *Lucasian chair* in mathematics at *Trinity College*, Cambridge. His *Lectiones mathematicae* and *Lectiones geometricae* joined the foundations of mathematics from the classical period with the current knowledge with respect to the determination of the volumes of curvilinearly bounded surfaces and to the tangent problem.

In early summer in 1665 – NEWTON had just obtained his bachelor's degree – all teaching at the university was halted on account of an approaching epidemic of plague, and NEWTON returned to the isolation of Woolsthorpe. In the ensuing two years, he conceived the basic ideas behind the grand theories that today are associated with his name:

- the differential and integral calculus, the theory of gravitation, and the theory of optics.



After the danger of the plague had passed, NEWTON was rapidly named a "fellow" and then a "master", and in 1669, when BARROW was appointed *King's Chaplain*, he was appointed to the Lucasian chair that BARROW had vacated.

BARROW used his influence effectively to promote NEWTON's theories in the scientific world, but NEWTON quickly withdrew his manuscript of the paper *De Analysi per aequationes numero terminorum infinitas* (on analysis by equations infinite in number of terms).

In this paper, NEWTON shows, among other things, how one can calculate directly the coefficients in binomial formulas (that is, not line by line using the schema that we know as PASCAL's triangle).

The general binomial series can be written as follows (in today's notation):

$$(1+x)^n = 1 + n\cdot x + \frac{n\cdot(n-1)}{2}\cdot x^2 + \frac{n\cdot(n-1)\cdot(n-2)}{3\cdot 2}\cdot x^3 + \frac{n\cdot(n-1)\cdot(n-2)\cdot(n-3)}{4\cdot 3\cdot 2}\cdot x^4 + ...$$

Thus, for example,

$$(1+x)^3 = 1 + 3x + \frac{3\cdot 2}{2}\cdot x^2 + \frac{3\cdot 2\cdot 1}{3\cdot 2}\cdot x^3 + \frac{3\cdot 2\cdot 1\cdot 0}{4\cdot 3\cdot 2}\cdot x^4 + ... = 1 + 3x + 3x^2 + x^3$$

Such a series development is also possible for negative and fractional exponents:

$$(1+x)^{-3} = 1 - 3x + \frac{(-3)\cdot(-4)}{2}\cdot x^2 + \frac{(-3)\cdot(-4)\cdot(-5)}{3\cdot 2}\cdot x^3 + \frac{(-3)\cdot(-4)\cdot(-5)\cdot(-6)}{4\cdot 3\cdot 2}\cdot x^4 + ...$$
$$= 1 - 3x + 6x^2 - 10x^3 + 15x^4 - ...$$

Newton's "proof" of the correctness of this result follows by multiplying out:

In the product $(1+x)^3\cdot(1-3x+6x^2-10x^3+15x^4-...)$ all the terms with positive exponents add to zero, and all that remains is the number 1.

An analogous result is obtained with the square-root function:

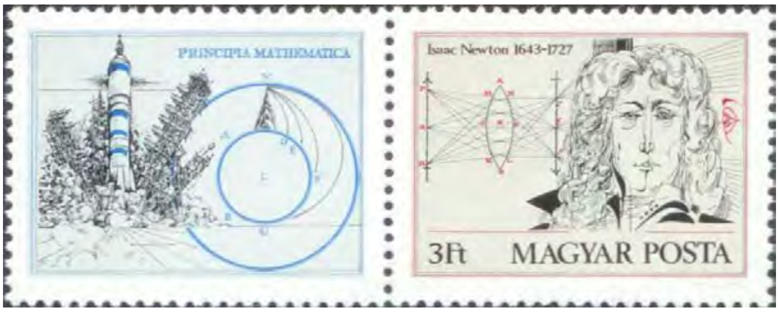
$$(1-x)^{\frac{1}{2}} = 1 + \frac{1}{2}\cdot(-x) + \frac{\frac{1}{2}\cdot(-\frac{1}{2})}{2}\cdot(-x)^2 + \frac{\frac{1}{2}\cdot(-\frac{1}{2})\cdot(-\frac{3}{2})}{3\cdot 2}\cdot(-x)^3 + ...$$
$$= 1 - \frac{1}{2}x - \frac{1}{8}x^2 - \frac{1}{16}x^3 - \frac{5}{128}x^4 - \frac{7}{256}x^5 - ...$$

In the case, the proof of correctness of the series development is obtained by squaring the infinite sum. Using this method, the extraction of a root is considerably simplified. For example, an approximate value for $\sqrt{3}$ can be calculated in the following way:

$$\sqrt{3} = \sqrt{4\cdot\tfrac{3}{4}} = 2\cdot\sqrt{1-\tfrac{1}{4}} \approx 2\cdot(1-\tfrac{1}{2}\cdot\tfrac{1}{4}-\tfrac{1}{8}\cdot\tfrac{1}{16}) \approx 1{,}734$$

NEWTON used this new technique of series development that he had devised to determine the areas under curves. In his paper can be found a rule in which one can recognize a standard formula for the integral: *If* $ax^{\frac{m}{n}} = y$ *it shall be* $\frac{an}{m+n} \cdot x^{\frac{m+n}{n}}$ *= Area.*

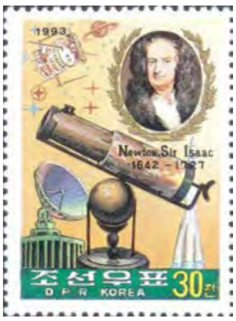
Using this, he also calculated, among other things, the area under the arc of a circle, thereby determining the value of π to fifteen decimal places.



The infinitesimal calculus developed by NEWTON (*method of fluxions* and *inverse method of fluxions*) is very strongly oriented toward physical ideas:

He conceptualizes a curve as a continuous motion of a point; he calls the time-dependent variables *fluents* (flowing quantities), and the rate of change of a quantity *y* is called its fluxion $\dot{y}$. For an infinitesimally small interval of time he employs the letter *o*, while he notates the infinitesimally small increase in the fluent *x* in the infinitesimally small time interval *o* (that is, the instantaneous velocity in an infinitesimally small time period) as $\dot{x}o$.

To calculate the slope of a tangent to a curve, one has only to compute the ratio $\dot{y}/\dot{x}$; here the truncation rule *replace* $x + \dot{x}o$ with *x* is applied. He recognized that in general, the fluxion of the region enclosed by a curve is the curve itself – and this is nothing other than the fundamental theorem of differential and integral calculus. NEWTON discovered it in 1665, but he published his findings only in 1704.



NEWTON devoted his first lectures as professor at Cambridge not to analysis, but to optics. Departing from the teachings of ARISTOTLE, he championed the point of view that white light is composed of light of various colours. From the fact that a prism refracts light at differing angles depending on the colour, he concluded that every lens must suffer from a certain aberration (which today we call *chromatic aberration*), and he subsequently constructed a reflecting telescope. This brilliant invention led to his induction into the *Royal Society* as a *fellow*.

However, he experienced considerable opposition from ROBERT HOOKE and CHRISTIAAN HUYGENS on account of the corpuscular theory of light that he promoted. NEWTON's reaction to that criticism was irrational. He withdrew and decided no longer to publish anything. His *Optics*, for example, did not appear until a year after HOOKE's death.

It was only EDMOND HALLEY who was able to drag NEWTON out of his lethargy and convince him to present his new physical worldview in book form. NEWTON's *Philosophiae naturalis principia mathematica* appeared in 1687. In it is to be found the law of universal gravitation:

- *All matter attracts all other matter with a force proportional to the product of their masses and inversely proportional to the square of the distance between them.*

NEWTON was able to show that from the law of gravitation one could derive KEPLER's laws of planetary motion, and conversely. With the three fundamental principles of classical mechanics, which today are known as *NEWTON's laws of motion*, he created a unified worldview that did not need modification until *EINSTEIN's theory of relativity* in the twentieth century:

- *Every body persists in its state of being at rest or of moving uniformly straight forward, except insofar as it is compelled to change its state by force impressed* (principle of inertia).
- *A force acting on a body is equal to the product of its mass and its acceleration* (principle of action).
- *To every action there is always an equal and opposite reaction or: the forces of two bodies on each other are always equal and are directed in opposite directions* (principle of interaction).

The year of publication of the *Principia* coincided with a period of unrest in the history of England: civil war and the execution of King CHARLES I (1649), dictatorship under OLIVER CROMWELL, restoration of the monarchy (1658). CHARLES II, son of the executed king, became the new ruler in 1660. He was succeeded in 1685 by his younger brother, JAMES II. JAMES, however, strengthened the position of the Catholic Church, which prompted resistance by Protestant groups, who eventually offered the English throne to WILLIAM OF ORANGE, governor of the Netherlands. After the Glorious Revolution in 1688, the powers of the Parliament were increased (*Bill of Rights*). NEWTON, a convinced Protestant, was chosen as representative of the University of Cambridge to the new Parliament.

Following a breakdown, NEWTON suffered continually from depression and withdrew more and more from research. He accepted the position of *Warden of the Royal Mint* in London and busied himself with the reform of English coinage. In 1703, he was elected president of the *Royal Society* and was knighted. Every year, he was reelected to that position. On his death, he was buried in *Westminster Abbey* following a state funeral.

His last years were overshadowed by an acrimonious dispute over who was the actual "inventor" of the infinitesimal calculus. Due to its more satisfactory notation and earlier publication in 1684, the method discovered by GOTTFRIED WILHELM LEIBNIZ was better known among mathematicians on the Continent.

This priority dispute developed into a question of national honor, which a partisan commission of the *Royal Society* under the leadership of HALLEY "decided" in NEWTON's favour.

Today, it is known that each theory was developed independently of the other.

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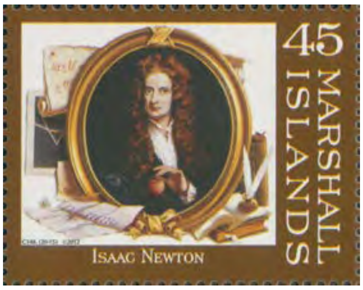


1642 Newton's Birthplace
1661 Trinity College, Cambridge
1665 Newton's Apple
1672 Fellow of the Royal Society
PRINCIPIA
1687 Publication of PRINCIPIA
1689 MP for Cambridge University
1700 Master of the Mint
OPTICKS:
TREATISE
1704 Publication of OPTICKS
1705 Knighted by Queen Anne
1727 The Death of Isaac Newton
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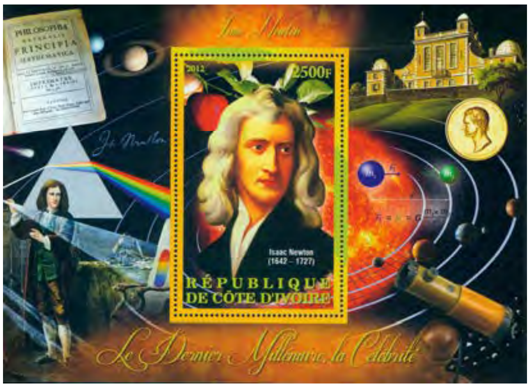

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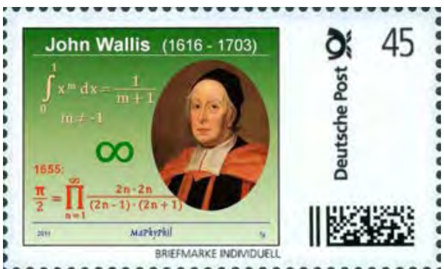

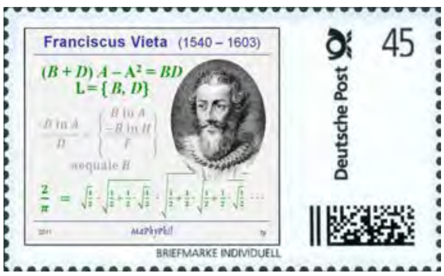

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