Biographical Encyclopaedia of Astronomers, 2007

Newton, Isaac

Born **Grantham, Lincolnshire, England, 25 December 1642**
Died **London, England, 20 March 1727**

Newton was born as a fatherless child on Christmas Day. He was then given by his mother Hannah at 3 years to be reared by his grandmother. The young Isaac did not receive undue parental nurturing. There were stories of how his youthful inventions alarmed the inhabitants of Grantham village, such as a night-flying kite that carried a lit candle. The sundial he constructed as a youth is now owned by the Royal Society of London.

After a grammar school education in Grantham, Newton entered Trinity College, Cambridge, in June 1661 and was chosen as a scholar in 1664. In 1669, the college elected him a fellow and the university, through the influence of **Isaac Barrow**, the incumbent, appointed him Lucasian Professor of Geometry.

In December 1671 Newton presented a 2-in.-diameter reflecting telescope —the first ever constructed—to the Royal Society, which led to his election as a fellow. The telescope had a short lifetime because its mirror surface clouded over in a fortnight: It took over a century for nontarnishing reflectors to be made. This was swiftly followed by Newton's 1672 "New theory of light and colour," sometimes viewed as the first scientific paper. This had the effect of promoting his new reflecting telescope design by exaggerating the chromatic aberration from which refracting telescopes suffered. This exaggeration, which disturbed **Robert Hooke** and **John Flamsteed**, was reinforced in Newton's *Opticks* of 1704, and effectively blocked achromatic lens development until 1740.

Using a prism and a chink of sunlight, Newton claimed to demonstrate that white light was *composed of* various colored rays that had merely been separated by the prism. Hooke disagreed, commenting that he could not see the necessity for such an inference. Th en, drawing from his alchemical studies, in a 1675 letter to the Royal Society , Newton formulated his immortal concept of the seven colors of the rainbow, inserting a seventh hue that no one could see.

Newton was taught the new physics of **René Descartes** , and accepted the Cartesian vortex theory of planetary motions, adhering to it until the early 1680s, but he modified it with his own view of a downward-flowing gravity ether: This had a "sticky and unguent" nature as it pulled objects downward, as he explained in his 1675 letter. He was, at the time, immersed in the alchemical tradition, and this theory emerged from it. Modern Newtonian scholarship has shown that Newton's early computations in the plague years concerning the *conatus recedendi* (or tendency of the huge ethers rotating round the Sun to recede) cannot be seen as an early perception of the inverse-square law of gravitational attraction, contrary to several centuries of interpretation.

Around 1679/1680, in addition to his arduous alchemical labors on such matters as preparing the elixir and fixing antimony, Newton's major interest lay in decoding the Apocalypse in order to analyze a presumed theological heresy of the fourth century concerning the Holy Trinity. The Platonist philosopher Henry More at Trinity recorded the enthusiasm with which Newton participated in discussion on such issues. We should therefore hesitate before accepting the received notion that Newton then linked **Johannes Kepler** 's first two laws of planetary motion to dynamical principles, as he later claimed and as many books have repeated. But no documents of this character exist (as historian D. T. Whiteside demonstrated) dateable prior to the autumn of 1684, when, at **Edmond Halley** 's bidding, he struggled with the great problem, and solved it.

As a student, Newton had observed the comet of 1664 (C/1664 W1), but it was too distant for any orbital parameters to be inferred. The comets of C/1680 W1 and 1p//1682 Q1 (Halley) were decisive for his thinking, with characteristics that seemed to be pointing to features of the to-be-born gravity theory. That of 1680 had its perihelion a mere fraction of the solar radius, yet was well outside the plane of the Solar System and so had little implication for the solar-vortex theory. Newton scrutinized it and received data from Flamsteed, after which he declined to believe what Flamsteed was telling him, that "ye two comets," one of which faded away in the evening sky and the other of which reappeared in the morning sky a week later, were one and the same. Years later, the comet merited 17 pages of his *Principia* for its parabolic orbit—but, in 1680, discussing its motion in the context of his vortex theory with Flamsteed, he preferred **Giovanni Cassini** 's view that it was in orbit round Sirius. Hooke's seminal words to him, written on 6 January 1680, that throughout the Universe a force of gravity worked so that "the Attraction is always in a duplicate proportion to the distance from the Center Reciprocall …" had hitherto lain dormant in his mind. Then the only bright, periodic comet (later named after Halley) conveniently turned up in 1682, orbiting within the ecliptic plane but in the reverse direction to the planets, and this acted as a trigger.

Newton's alchemical laboratory fire then went out for a couple of years. In the summer of 1684, following a visit of Halley, a more austere, left-brain process began as he apprehended that the "two comets" of 1680 were in fact one. In November of 1684 Halley received a draft of *De Motu* , which employed the inverse-square law. Newton there demonstrated the link to Kepler's first and second laws, using a cumbersome logic based upon relative volumes. Dealing with small changes in an elliptical orbit, it was a rudimentary integration procedure. The proof thus laboriously constructed required the rest of *De Motu* as its context, because it used the concepts there developed of force, impulse, and momentum conservation.

In the spring of 1685, Newton accomplished his "moon-test" computation, justly his most famous. For his predecessors, the 27.3-day sidereal lunar orbit had carried an astral meaning, from the Moon's passage against the starry constellations, but Newton ignored that and viewed it only as resulting from a central force. He became able in the 1680s to compute acceleration by a centripetal force. "If stopped," he explained, the Moon would fall a distance in 1 minute, equal to the distance an object on Earth would fall in 1 second; a 60-fold ratio was employed, related to the 60 Earth-radii lunar distance. There was no computation of acceleration, of "g," despite the many textbooks that have averred this. Newton was now able to treat uniform circular motion as accelerated, toward its center.

Then began the great synthesis of many physical ideas in the 2 ½ years during which Newton wrote his *Principia* , from the autumn of 1684 to March of 1687. **Nicolaus Copernicus** had made the Sun stationary, which Newton transformed into the immobility of the Solar System's center of mass. Newton incorporated the work of **Galileo Galilei** , who had first discerned accelerated motion in free fall, where distance fallen in equal times goes as the sequence of odd numbers and is the same for all objects, replacing the old notion that heavy bodies fall faster. Descartes, and now Newton, affirmed that one physics should link the Earth and sky, demolishing the old duality between the "sublunary" world and the immutable heavens: Newton extended the work of **Jean Buridan**, who had developed the notion of impetus, whereby a body keeps moving, in place of **Aristotle**'s notion that a body moves so long as it is pushed. Robert Boyle had described a vacuum at the top of a mercury column, which Newton now envisaged throughout the immensity of space; Newton derived Kepler's three laws of planetary motion, which had ellipses replacing circular epicycles; Barrow, Newton's mathematics teacher at Trinity, had taught a rudimentary calculus concerning "just nascent quantities," which Newton employed to describe the motions of bodies; last but not least, from Hooke came Newton's inverse-square law of gravitational attraction. A new universe gleamed, rational to the core.

In dealing with the three-body problem, Newton's calculations were given to five decimal places and eight figure accuracy, generating a huge error (200%) for lunar mass. He found the Earth–Moon mass ratio to be 22:1 rather than the currently accepted 81:1. Newton thus left to posterity an ultra-dense Moon. As a result, his first computation of the Earth–Moon barycenter in 1713 (for the *Principia's* second edition) located it outside the Earth, from which derived the main error in his historic computation, linking the fall of an apple to the lunar orbit.

Newton also explained why the Earth has two tides a day, a question that had so baffled Salviati and Sagredo in Galileo's *Dialogue* , and indeed many previous natural philosophers. Newton formulated the inverse-cube law of tidal pull, whereby "the force of the moon to move the sea varies inversely as the cube of its distance from the earth." This accounted for the Moon having a larger tidal pull than the Sun, although having only a tiny fraction of its gravity. Thereby he could explain why there are two high tides a day aligned with the Moon. Newton intuited this law with little by way of explanation, so his contemporaries such as Halley and **David Gregory** attempting to explain this tidal argument could do so only in a qualitative sense.

The mighty synthesis thus accomplished had no practical use to astronomers. British ephemerides (for planetary and lunar positions) were not improved: Paris became the main center of their production over this period. After his 1693 nervous breakdown, Newton made one further scientific endeavor. He grappled with lunar theory in 1694/1695, using Flamsteed's new, high-precision data. This was the supreme scientific problem of the age, holding out the promise of finding longitude at sea. Could Newton explain the Moon's erratic path using his gravity theory, since the rest of the Universe obeyed it? He could not (in Whiteside's view). His hitherto respectful partnership with Flamsteed suffered from this, with a (successful) ploy of laying the blame for the failure upon the astronomer, as if he had demurred in sending the data. A fruit of this struggle appeared in 1702, with a lunar "theory" as was, paradoxically, not evidently based upon gravitational principles. This 1702 opus was the most frequently reprinted work of Newton's in the first half of the 18th century: In seven steps of "equation" it obtained a final lunar longitude, accurate to several arc minutes.

A modified version appeared in Book III of the *Principia's* 2nd edition of 1713. Thus began the idea of ancillary equations, as a means of solving the three-body problem.

Newton reintroduced epicycles into astronomy, a century aft er Kepler had banished them: His neo-Horroxian 1702 lunar theory was laden with four of them, and as such they reappeared in his *Principia* . French sources could never believe that this model with its wheels moving upon wheels had been deduced from gravity theory, while English histories soon managed to retell the story using the mid-18th-century theories of **Leonhard Euler** or **Tobias Mayer** as being "Newtonian."

In his *Algebra* of 1685, **John Wallis** commented upon a mathematical tract of the 1660s by Newton, *De Analysi*, which Newton would not allow to be published; while admiring certain conventions and nomenclature, Wallis perceived in it no germ of a new fluxions theory, nor did anyone else in the 17th century, despite wide circulation of the manuscript. Only retrospectively, during the great fluxions battle with **Gottfried Leibniz** at the beginning of the 18th century, were such claims fi rst advanced. (The *Principia* contained integral but not differential calculus, the former having developed somewhat earlier than the latter.) Newton's *Arithmetica Universalis* published in 1707 and taken from his mathematical lecture notes of the 1680s, compiled by **William Whiston**, enjoyed a much greater popularity in its time than either the *Principia* or *Opticks,* but it contained no trace of fluxions, Newton's term for the differential calculus, and rather argued against the concept of introducing arithmetical terms into geometry.

Albert Einstein once declared that, "the solution of the differential law is one of Newton's greatest achievements," but the equations $F = ma$ and $F = m\mathrm{d}v/\mathrm{d}t$ were invented around 1750 by Euler in Berlin; no one in Newton's lifetime had heard about them. The Berlin Academy of Sciences showed no inclination to view Euler's great discoveries as having been anticipated. What the *Principia* stated was, merely, "change of motion is proportional to motive force impressed" with quantity of motion having been earlier defined as the product of mass and velocity. That was a statement about impulse as proportional to change in momentum and uses no rate-of-change concept. As I. Bernard Cohen has observed, Newton never wrote anything resembling F=kmv. The *Principia* with its geometrically structured proofs, achieved a depth of inscrutability unmatched by any other scientific text. Much of what is called "Newtonian" science is the reformulation of Newton's work using Leibnizian calculus , a task accomplished largely on the Continent in the 18th century.

The myths that surround the image of Newton tend to exaggerate the extent to which he used "fluxions," but not always. for example it is often asserted that he developed the gravity-pull formula $F = GMm/r^2$, a formula which was not, in fact, published in his lifetime. In "a famous but delusive phrase" (Rupert Hall), Newton averred in 1712 that his masterwork had first been composed in fluxional terms and then, later on, recast into a geometrical format. Generations of historians have reaffirmed that Newton had first composed his *Principia* in fluxional form and then recast it into its inscrutable geometric format, but not until 1975 did D.Whiteside disprove this notion and lay it to rest.

"Newton's method of approximation" was invented in 1845 by John Simpson, known today for his "Simpson's method" for finding the approximate area under a curve. It is an iterative technique where the same equation is reused, and employs the Leibnizian calculus. Newton's own method of approximation, described in his *De Analysi* and which he used to solve the "Kepler equation" for elliptical motion, was neither iterative nor fluxional. For each step of approximation it generated a new and different equation.

Simpson was not eminent enough to hang onto the credit for his invention, which became attributed to Newton in the latter half of the 18th century.

Few paid Newton more golden compliments that did Leibniz: "taking mathematics from the beginning of the world to the time of Sir Isaac, what he had done was much the better half," he wrote to the Queen of Prussia in 1701. But after his mistreatment by the Royal Society in the fluxions dispute, he described Newton as "a mind neither fair nor honest." Leibniz first published papers on the differential calculus in 1684; these were seminal for the European development of the subject. Newton's first work on the subject appeared in 1704, *De Quadratura*, which gave what we would call implicit functions. It did not describe time-dependent functions or how to find the gradient of a curve, and was primarily about methods of integration.

Newton wrote over a million words on chemistry/alchemy, and believed that transmutation could possibly make or unmake gold, as expressed in his one published chemical/alchemical text, *De Natura Acidorum* (1710), which described that process. He read alchemical texts eagerly, but seems not to have written like an alchemist; he sought no path of redemption or perfection through such labors. Ultimately, his relation to the western alchemical tradition was that of terminator. Once his *Opticks* had affirmed the atomic view ("God in the Beginning form'd Matter in solid, massy, hard, impenetrable moveable Particles … even so very hard, as never to wear or break in pieces"), the colorful language of alchemy then had to transform into particulate affinity theory, during the 18th century.

Hardly was the ink dry from his *Principia* in March 1687 when Newton was elected to represent Cambridge University in Parliament in an attempt to defy the king's promotion of Roman Catholic professors. This morally courageous act put his career at risk and got him sternly rebuked from the feared Judge Jeffreys. Two years later the king had fled the country, Jeffreys was in the Tower, and Newton was in Parliament. When in 1695 he became Warden of the Mint, the nation's recoinage was successful, and the Bank of England first floated paper money, a difficult exercise in credibility. When Newton was elected President of the Royal Society in 1704, its membership and prestige climbed steadily. From being the most reclusive of scholars, where most of the tales about him concern his absent-mindedness, he became a man of public affairs: Member of Parliament, Justice of the Peace, Knight, President of the Royal Society, and Master of the Mint. In his religious views, Newton was probably a mortalist (disbelieving in human survival after death) and an anti-Trinitarian, either of which would have utterly debarred him from holding public office.

In the last year of his life, in a Kensington garden far from the bustle and fumes of London, and while having tea with **William Stukeley**, Newton first told his story of the apple. Thus had the law of gravity dawned upon him. He located it in 1666, as London burnt and the plague raged. Earlier narrations, beginning in the 1690s, had involved his Mother's garden at Grantham but lacked mention of this fruit. The neo-Biblical simplicity of this story proved irresistible, and it has flourished ever since.

Nicholas Kollerstrom

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