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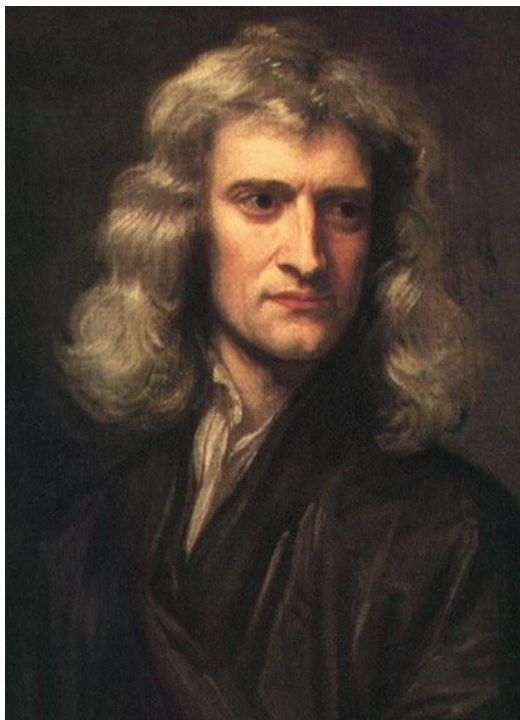
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## Newton, (Sir) Isaac

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1642/1643–1726/1727 (The difference is due to the use and report of the date in two calendars: Julian and Gregorian. According to the Gregorian calendar, the date of Newton's birth was 4 Jan, 1643 and that of his death 31 March 1727) (Portrait of Isaac Newton in 1689 (age 46) by Godfrey Kneller, Wikimedia)

### Biography

Isaac Newton was an English physicist and mathematician, who made seminal contributions to several domains of science, and was considered a leading scientist of his era and one of the most influential scientists of all time. He was born prematurely on 25 December 1642 in Lincolnshire, England, of Hannah Ayscough and Isaac Newton (father) [1]. His father passed away before he was born. His mother remarried when he was 3 years old and he was left in the care of his grandmother, a situation he resented.

He attended the King's School in Grantham where he learned Latin among other things until the age of 17. In 1661, he was admitted to Trinity College, Cambridge, and was educated in Aristotelian philosophy. However, Newton also read the works of Descartes, Galileo, and Kepler. In 1665/1666 he spent most of the time at his ancestral place in Lincolnshire because of the dangerous spread of plague in Cambridge.

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During that time he did most of his experimental work with glass prisms and much of his mental work that resulted in the publication of *Principia* in 1687.

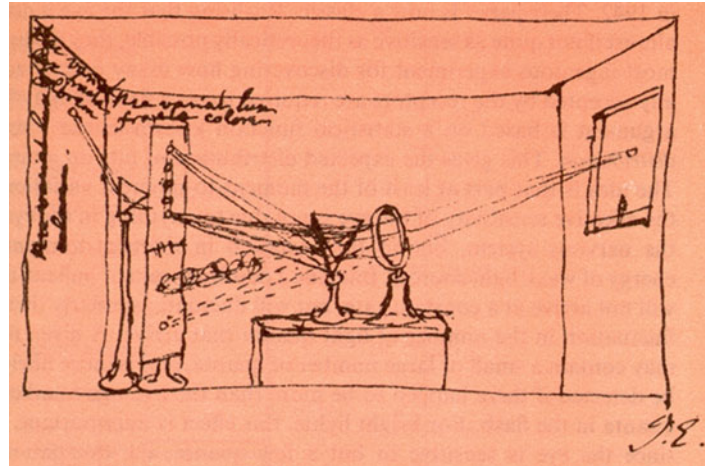
In 1667 he returned to Cambridge and became a fellow of the College of the Holy and Undivided Trinity [2, 3]. In 1669, and at the age of 26, Newton became the Lucasian professor of mathematics. According to his secretary Humphrey Newton (no relation), his lectures were often poorly attended and few understood him and that sometimes he read to the walls [4]. Newton occasionally traveled to London to attend the Royal Society lectures and was named a fellow in 1672. He became its president from 1703 to 1727. Newton was given various levels of support by the Royal Society. His interpretation of the optical experiments was strongly disputed by Robert Hooke, an employee of the society since 1664, as a result of which he published his book *Opticks* only in 1704, after Hooke's death. He was supported by the society in his bitter and controversial dispute with the German polymath and philosopher Gottfried Wilhelm Leibniz over who had developed calculus first [Leibniz's notations are used today].

Newton also dwelt in politics and was a member of the House of Commons between 1689 and 1690 and then again from 1701 to 1702. In 1705 he was knighted by Queen Anne during her visit to Trinity College. He held two government offices: first he was the Warden of the Mint from 1696 to 1700 and then Master of the Mint from 1700 until his death in 1727. At the time of Newton's funeral, the French philosopher Voltaire who was in England compared Newton to Descartes and said of Newton that "he was never sensible to any passion, [and] was not subject to the common frailties of mankind, nor had any commerce with women" [5]. Newton had strong opinions on religion and wrote a number of works, not published during his lifetime, that would have then been considered heretic in that period. Newton never married and died intestate in Kensington, London, when his relatives quarreled over the division of his considerable estate. He is buried in Westminster Abbey in London, England.

## Major Accomplishments/Contributions

### Newton's Theory of Color

Arguably our modern understanding of light and color begins with Newton's discovery of light dispersion which he published in 1672. In the late 1660s, Newton started experimenting with the phenomenon of colors and lectured on optics [6]. At the time, it was generally thought that colors were mixtures of light and darkness. It was also believed that prisms imparted colors to light. Through observation of light refraction, Newton realized that this theory was incorrect. He demonstrated that a prism decomposes "white" light into a spectrum of colors. Newton obtained a triangular prism and began "to try therewith the celebrated Phaenomena of Colours." In his notes he states, "having darkened my chamber, and made a small hole in my window-shuts, to let in a convenient quantity of the Sun's light, I placed my Prisme at this entrance, that it might be thereby refracted to the opposite wall. It was at first a very pleasing divertissement, to view the vivid and intense colours produced thereby; but after a while applying myself to consider them more circumspectly, I became surprised to see them in an oblong form, which, according to the received laws of Refraction, I expected should have been circular" [7]. The original sketch demonstrates the dark room environment where this experiment was conducted (Fig. 1). He was the first to use the word spectrum (Latin for "appearance" or "apparition") in this sense. He also used additional prisms to recombine the split components and showed that a spectral colored light does not change its properties by separating out a colored beam and shining it on various objects regardless of whether it was reflected or scattered or transmitted. With respect to colors Newton said "For the rays, to speak properly, are not coloured. In them there is nothing else than a certain power and disposition to stir up a sensation of this or that Colour" [4]. During this period he also investigated the refraction of light and demonstrated that a multicolored spectrum produced by a prism could be recomposed into "white" light



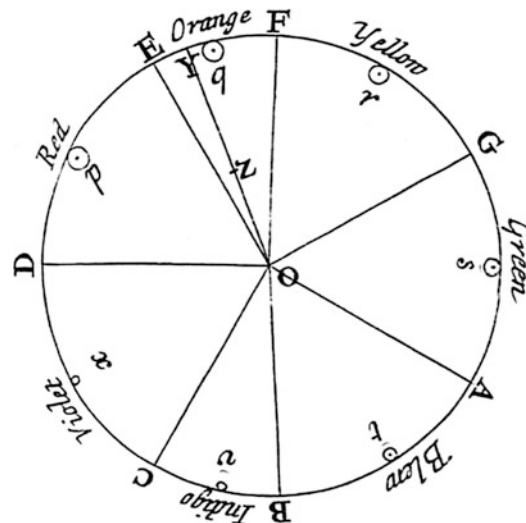
**Fig. 1** Newton's sketch of refracting sunlight with a prism. The experiment shows light passing through a hole and then collected by a lens and focused on the prism which then refracts white light into its spectral components. The experimental sketch also shows a second prism that is used to show a narrow band light is not further decomposed. A separate experiment was used to show the reversibility of the process

by a lens and a second prism [8]. In the same period Newton observed that the angle of refraction of different colors by a prism is different [9]. He noted that even when light rays in the form of a circular beam enter a prism, the spectrum of colors that exit in the position of minimum deviation is oblong. The length of the colored spectrum was in fact about five times as great as its breadth. He stated that it is the interaction of the object with light that creates the color of the object and not the object itself. This is known as Newton's theory of color.

From this work, Newton concluded that the lens of any refracting telescope would be adversely affected by the dispersion of light into colors. This is also referred to as chromatic aberration. He constructed the first reflecting telescope in late 1668 using a mirror to avoid this problem, and this resulted in the first known functional reflecting telescope, which is today known as a Newtonian telescope [10]. Newton used a custom composition of highly reflective speculum metal to grind his own mirrors and then employed what is now known as “Newton’s rings” to judge the quality of the optics for his telescopes and demonstrated his device to the Royal Society in 1671 [11]. Their interest resulted in Newton publishing his notes, *Of Colours* [12], which was later expanded into his book *Opticks*. Newton was the first to demonstrate the use of a prism as a beam expander in his book and he describes, via diagrams, the use of multiple-prism arrays. Some 278 years after Newton’s discussion, multiple-prism beam expanders became central to the development of narrow-linewidth tunable lasers.

In 1704, Newton also discussed the corpuscular theory of light whereby light is considered to be made up of extremely small particles (which we now call photons). Newton argued that light is composed of particles or corpuscles, which were refracted by accelerating into a denser medium. To transmit forces between particles, Newton posited the existence of the ether. However, he replaced ether with occult forces based on Hermetic ideas of attraction and repulsion between particles and Newton's considerable writings on alchemy. It has been said that "Newton was not the first of the age of reason: He was the last of the magicians." Indeed, Newton's interest in alchemy cannot be isolated from his contributions to science [11] since during his time there was no clear distinction between alchemy and science.

Later physicists favored a purely wavelike explanation of light to account for the interference patterns and the general phenomenon of diffraction. Later on, Young and Fresnel combined Newton's particle theory with the wave theory and indicated that color is the visible manifestation of light's wavelength.



**Fig. 2** Colors and the associated musical notes in Newton's color wheel, shown in his book *Opticks* of 1704. The circle completes a full musical octave, from D to D [8]. Colors on opposite sides are complementary

## The Color Circle

In his observation of white light dispersion into spectral components, Newton divided the spectrum into seven named colors: violet, indigo, blue, green, yellow, orange, and red. He placed the colors in a circular fashion and called it a color circle and used it to demonstrate the results of mixtures of spectral lights, including complementarity (those that when mixed cancel each other out and result in white, gray, or black). The size of each segment differed from the other according to his calculations of its wavelength, the seven musical tones or intervals of the eight sounds and of its corresponding width in the spectrum. The choice of seven colors was out of a belief, derived from the ancient Greek, that colors, objects in the solar system, the musical notes, and the days of the week were connected. This likely explains the selection of indigo as another hue between blue and violet. Some argue, however, that in Newton's prismatic colors, "indigo" would be placed as a color that is today called blue, whereas "blue" would correspond to cyan (Fig. 2).

Newton proposed a method to determine the "fullness or intenseness" of combined colors on the circle based on the distance of the center of the combined gravity of the circles for each of the rays of light from whiteness (the distance from O to Z in the figure shown for Color Y, which arises from the composition of all the colors in the given mixture). The color circle was, if lacking the nonspectral colors, an early representation of what became centuries later, in a modified form, the chromaticity diagram. In his system, Newton had connected violet to red in the circle, and thus, a large gamut of purples was not shown. Newton described the complementary colors and their mixture and stated "If only two of the primary colours which in the circle are opposite to one another be mixed in an equal proportion, . . . , the colour compounded of these two shall not be perfectly white, but some faint anonymous colour." [8]. Newton's concept of complementary colors was demonstrated more thoroughly in the nineteenth century by color theorists. Helmholtz established the complementary stimulus pairs, and Ogden Rood (1831–1902) emphasized that to reveal applied colors in their natural brilliance, a knowledge of the complementary hues was required [13].

A version of Newton's color circle without the indigo blue was adopted by painters to describe complementary colors. Nonetheless, this circular diagram became the model for many color systems of the eighteenth and nineteenth centuries. The conceptual arrangement of colors in this form also allowed





**Fig. 3** Newton was the Warden and then the Master of the Royal Mint in England, and his picture appeared on the one pound note, almost three centuries later [15] (With permission to reprint from the Bank of England)



**Fig. 4** An image of a German stamp commemorating Newton's 350th birthday [16]

the painters' primaries (red, yellow, blue) to be arranged opposite their complementary colors (e.g., red opposite green), as a way of denoting that each complementary color would enhance the other's effect through optical contrast.

In addition to his work on optics, Newton made seminal contributions to several other scientific disciplines. In his book the *Principia* or "*Mathematical Principles of Natural Philosophy*," which was published in 1687, Newton formulated the laws of motion and universal gravitation and is considered to have laid the foundations for classical mechanics [14]. He also introduced the notion of a Newtonian fluid, studied the speed of sound, and developed an empirical law of cooling among other major contributions made to scientific discovery. Newton's image appeared on the Bank of England notes for about 10 years in the 1970s and 1980s [15]. He has also been commemorated on various stamps and coins [16] (Figs. 3 and 4).

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