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# Newton: 'Opticks'

Reflections on the various works in the exhibit

# Imprints and Impressions: Milestones in Human Progress

Highlights from the Rose Rare Book Collection, Sept. 29-Nov. 9, 2014

Roesch Library, University of Dayton

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Isaac Newton

*Opticks: Or, a Treatise of the Reflexions, Refractions, Inflexions and Colours of Light*

- London, 1704
- First edition

**Reflection 1**

How is a rainbow formed? Why do I see colors like magenta, yellow, and turquoise blue on an oily puddle or when my kids blow soap bubbles? Why does a prism project the colors of the rainbow on the wall? And why are all the really big telescopes based on mirrors and not lenses, which was the technology used by Galileo?

Newton answered all of these questions and many more while performing experiments in optics during the latter part of the seventeenth century. Galileo had made great use of the refracting telescope (one with lenses) a century earlier, but he did not have basic knowledge about the physical principles behind his instrument. Kepler made some progress in that regard, but it was up to Newton, working with the previously elaborated law of refraction (bending) of light rays, who synthesized several ideas into a comprehensive set of optical principles.

Perhaps the key point of Newton's observations was that white light is made up of a superposition of many different "rays" of light with different colors. Furthermore, each individual color of light, in a continuous spectrum, has its own property of "refrangibility," or refraction. When a ray of red light (such as a laser pointer) hits a glass surface at an angle, it will be bent as it passes into the new medium. A green laser beam is bent slightly more, a blue one more still, and so on. This explains the working of a prism, spreading out the different colors from the initial white light, and also is crucial in understanding the rainbow: As light rays from the sun enter a raindrop, they are refracted, reflected off the back of the droplet, and bent again as they exit toward our eyes.

Newton quickly realized that his experiments with prisms had an important technological consequence. A lens can be thought of crudely as two prisms put together base-to-base; therefore, blue and red light will always focus differently, and any image made with a refracting telescope must necessarily exhibit distortions in color that effectively make the objects being observed seem blurred. His solution came quickly in the form of a reflecting (now known as Newtonian) telescope based on the reflection of light from a mirror to an eyepiece for the observer. Since reflection of light from a surface does not depend on the wavelength (i.e., color) of the incident light, the aberrations due to refraction were eliminated.

Newton believed that light was made up of tiny particles; therefore, his language of rays was a reasonable one for describing the motion of those particles. During his investigation of refraction, he even posed the question as to whether the separation of red and blue light might be due to a kind of curveball effect induced on the light particles by the glass through which they were passing, an idea that seems to have come from watching the behavior of balls being hit in a game of tennis.

Newton made many observations of the properties of colored rings and bands of light formed by thin pieces of glass or thin films of oil, but he was not able to give a theoretical explanation of these phenomena because of his particle view of light. A complete explanation and more definitive experiments would have to wait for the nineteenth century and the work of Thomas Young and the electromagnetic wave theory of light developed by James Clerk Maxwell. Interestingly enough, however, at the beginning of the twentieth century, Albert Einstein returned to the particle theory of light to explain the so-called photoelectric effect, the work for which he was awarded the Nobel Prize.

Like Kepler with his astrology activities, Newton is a bridge figure in the history of science. He is perhaps the physicist whose name is invoked more than any other in the teaching of physics to students to this day, mainly for his contributions to mechanics and dynamics as put forth in the *Principia Mathematica*. Aside from the important contributions he made to the understanding of the laws of motion and optical principles, Newton also invented what we now call calculus as a mathematical tool to aid in his other work. As if this were not enough, he spent a great deal of his time in the laboratory performing alchemical experiments trying to transmute metals, for example. But the subject to which he devoted the greatest part of his writings was that of biblical exegesis, trying to construct literal interpretations of biblical events.

—*Robert Brecha, PhD, Professor, Physics*

### Reflection 2

Optics was a well-established discipline by the seventeenth century. However, though the production of mirrors, telescopes, microscopes, spectacles, and other optical instruments was well advanced, the methods were largely empirical, and there was no detailed understanding of the nature and behavior of light. The construction of a telescope, for example, was largely a matter of trying different lenses until a suitable combination could be found. Ideas of color were particularly confused. The subject was ready for a more disciplined approach. This was the essence of Isaac Newton's contributions and the thrust of his *Opticks*. He had already written his great work *Philosophiae Naturalis Principia Mathematica* (*Mathematical Principles of Natural Philosophy*) published in Latin in 1687, which enunciated the principles of classical mechanics, removing all the irrational and ill-formed ideas that had slowed science's advance. The same rational approach appears in the*Opticks*—significantly, in English (a Latin translation appeared only later).

Science is a community pursuit with communication as its lifeblood. It thrives by the sharing of information and ideas, and to encourage this, the Royal Society was established in 1662, while Newton was a student at Trinity College, Cambridge. By 1667, he had made significant contributions in what we now call calculus, and he had begun his work on gravitation. He had also made great progress in his studies of color and applied his ideas to the improvement of telescopes by the use of reflecting rather than transmitting elements to reduce chromatic aberration.

Newton reported his work on color and on reflecting telescopes to the Royal Society in 1671, and, to his considerable dismay, he was immediately ridiculed by Robert Hooke, who tried to advance his own vague ideas about pulses of light (white as a uniform pulse and color as a combination of red and blue in a compounded or perturbed pulse). From then onward, Hooke and Newton were implacable enemies.

Newton's ideas on optics and the nature of light and color were well advanced by this time, but it was not until 1704—the year following Hooke's death—that *Opticks* was finally published: "To avoid being engaged in Disputes about these Matters, I have hitherto delayed the printing, and should still have delayed it, had not the Importunity of Friends prevailed upon me."

Newton's method was to base everything on actual measurements. Speculation in the absence of evidence was futile. He established that there was a particular quality of light that was associated with its color response and with the degree to which it was refracted at a given surface, or its refrangibility. This quality was unalterable. The light itself was not colored. Color was a human response to the stimulation by the light. He made it clear that if he spoke of light as possessing a color, he would be speaking "accordingly to such Conceptions as vulgar People … would be apt to frame." He recognized the seven colors that we still associate with the spectrum; red, orange, yellow, green, blue, indigo, and violet, with red being the least refrangible and the violet the greatest. We have all seen the colors produced by sunlight in thin films of material, like oil floating on a puddle. Newton studied these colors in detail and included in the *Opticks* techniques, still completely valid, for accurate prediction of the colors of thin films.

Nowadays, we try to make our publications completely objective, and we appear to have lost the ability to include our thought processes. The *Opticks* vividly recounts Newton's attempts to understand what his data were telling him. He struggled with the true nature of light itself and for various reasons favored the corpuscular theory, although he tried hard to remain neutral.

*Opticks* was a very important publication not just for the unambiguous sets of rules of optical behavior, but also because it clearly demonstrated that it was possible to apply logical reasoning to science and technology to establish natural laws.

The book reads as well today as it must have in 1704. Not only is it one of the most significant texts in optics; it also paints a remarkable picture of the early development of the scientific method.

—*H. Angus Macleod, DTech,*
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