Willebrord van Roijen Snell

Dutch mathematician **Willebrord van Roijen Snell** (1580 – October 30, 1626) is best known for his discovery regarding the refraction of light rays. It became the basis of modern geometric optics, but only became known seventy years after his death when Christiaan Huygens mentioned it in his *Dioptrica*. Snell was born at Leiden in the Netherlands. He was a child prodigy who was said to have been familiar with all the standard mathematical works by the age of twelve. Despite this, Snell initially studied law at the University of Leiden, where his father, Rudolph Snell (or Snellius) was professor of mathematics and Hebrew. Willebrord Snell traveled to Prague to make observations with Tycho Brahe and Johannes Kepler. In 1608 he received an M.A. degree from Leiden and married Maria De Lange. They had eighteen children, of whom only three survived. In 1613 he succeeded his father, as professor of mathematics at Leiden after the latter's death.

Snell was very involved with geodesy, the application of mathematics to the determination of the size and shape of the Earth and the exact positions of points on its surface. In 1615 he established a network of cities forming triangles. A single measurement of a carefully selected baseline of just a few hundred meters enabled him to calculate the distance between all the communities via triangulation. He started with his own house, and using the spires of local churches as points of reference, mapped a substantial local area. He ultimately computed the distance between Alkmaar in the North and Bergen-op-Zoom in the South, a distance of 130 km. His study of astronomy allowed him to find the latitude of these towns, so he could calculate the distance between single lines of latitude, and therefore the circumference of the earth, which he reckoned to be 38,500 km, fairly close to the real figure of 40,000 km.

In 1617 Snell published *Eratosthenes Batavus* (1617), in which he explained his method of measuring the earth. It was the foundation of modern geodesy and earned Snell the title “the father of triangulation.” In *Cyclometricus* Snell calculated π to 34 decimal places, now known as Snell’s’ number. His most important discovery, known as Snell’s Law, or the second law of refraction of light waves, was made after much experimentation. He discovered that a beam of light bent when it passed into a block of glass. Snell’s Law of Sines states that when a light ray passes from a rarer to a denser medium, for instance from air to water (Figure 10.19), it is bent toward the normal (vertical line) and that the ratio of the sine of the angle of incidence (sin θ_1) to the sine of the angle of refraction (sin θ_2) is constant for a particular wave length. Snell died at age 46, never knowing the importance of his discovery of the basic laws of refraction or the prominent place his name occupies in physics and optics.

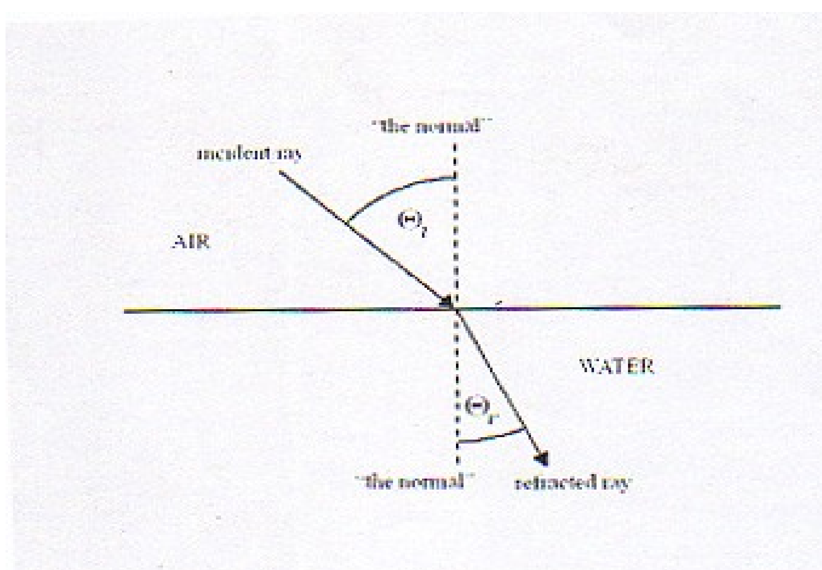

Figure 10.19

Reflection is one of the most important properties of light relating to fiber optics. Newton's law states, "The angle of incidence equals the angle of reflection," that is, sin θ_1 = sin θ_2. Refraction is another important property that light exhibits when traveling through different media. In 1860 Alexander Graham Bell demonstrated voice transmission using mirrors that were vibrated by the sound waves of the voice. The light reflected off the mirrors was modulated by the sound. Bell was able to focus the modulations onto a selenium plate, which resulted in resistance changes caused by changes in the intensity of the light. These changes then activated a speaker-like instrument. In 1870, John Tyndall concluded that light could follow a curved path as well as a straight line. At the turn of the century, Planck developed quantum theory. In 1905 Einstein explained the photoelectric effect using quantum theory. In 1930 William Lamb, Jr. made some of the earliest experiments with guiding light in a glass fiber, and in 1951 American researchers demonstrated the transmission of an image through a bundle of glass fibers.

Schoolchildren are taught that the speed of light is a constant 186,000 miles per second (300,000 km. per second), but that's not correct. It is only constant if it is traveling through a medium of constant density. When light encounters an increase in density, say, when it travels from air to water, it slows down. Changes in density cause the path of light to bend. When light encounters a decrease in density, say from water to air, it speeds up. Snell found the ratio of the changes in speed to be the ratio of angle of incidence to the angle of refraction. This common ratio for a given pair of materials is called the *refractive index*. If the incident light is in a vacuum, the speed of light in the second material is called the *absolute refractive index.* It is specific for each pair of media. By definition the refractive index of a vacuum is 1. Air makes little difference to the refraction of light, having an absolute refractive index of 1.0008. The absolute refractive index of water is 1.330, while that of a diamond is 2.42.

Following the teachings of Plato, the ancient Greeks thought that light rays emanated from the eye and intercepted external objects, which are thus seen by the observer. They also felt the speed of light was very high, perhaps infinite. The first person to realize that light travels from an object seen to the eye was the Arab philosopher “Alhazan (Abu’ali al-hasan ibn al-haytham), who published a work on optics in 1000 C.E. René Descartes was the first person to publish the now familiar version of the law of refraction in terms of sines in 1637. He apparently was unaware of Snell’s work. In English speaking countries the principle is known as Snell’s Law, but in France it is named Descartes’ Law.

Quotation of the Day: “Light brings us the news of the Universe.” – Sir William Bragg