SNELL'S LAW AND ITS CONSEQUENCES

Willebrord Snell (1591-1626) University of Leyden, the Netherlands, figured out in 1621 the not so obvious relationship between the incident beam and the change in the direct that a transmitted beam takes in a material. Unfortunately his discovery was not published in his lifetime.

There are 4 variables involved in Snell's Law; the angles in the two media, (although it is their sines that are related, not the angles directly) and the refractive indices of both media.

The refractive index of a material is a measure of its bending power. The higher the refractive index, the more the ray of light will bend as it enters or exits the material. Its mathematical abbreviation is n, as little i is used to denote the *imaginary number*, the square root of negative 1.

The refractive index is defined as the ultimate speed of light in vacuum· divided by the speed of light in the material:

n = c/speed of light in the material

The lowest refractive index is 1, the refractive index of the vacuum of space divided by itself. Denser materials which slow down light more have higher refractive indices, with the most common high index material being diamond, whose index rounded to one decimal point is 2.4. Some higher index materials are more obscure, like the Indium-Aluminum-Arsenic-Gallium combinations used to make laser diodes used in pointers with numbers greater than 4!

It is the slowing down of the light beam as it transitions from one medium to another that makes it change direction.

· = 299,792.458 meters per second

Snell's Law of Refraction can be written in a variety of ways, but an easy to understand form is:

$$n_1 \times \sin \theta_1 = n_2 \times \sin \theta_2$$

Usually three of the variables are given and you need to find the fourth. The n's, the refractive index of a material, are usually found in a database. It is a huge one, as every different transparent medium has a family of different refractive indices for every wavelength in the rainbow! See the penultimate page in the Postscript for this Unit for a selected table of them.

The first set of figures show the relative distances traveled by light in equal amounts of time in air and a denser transparent medium. Rounding the speed of light in air to 300,000 km/sec, it then travels 3 cm in 100 picoseconds in air. When it is incident to the second medium along the normal (meaning at a right angle) no bending takes place, just retardation in rate, so it travels less distance in the same length of time. This is shown to scale in the drawing below.

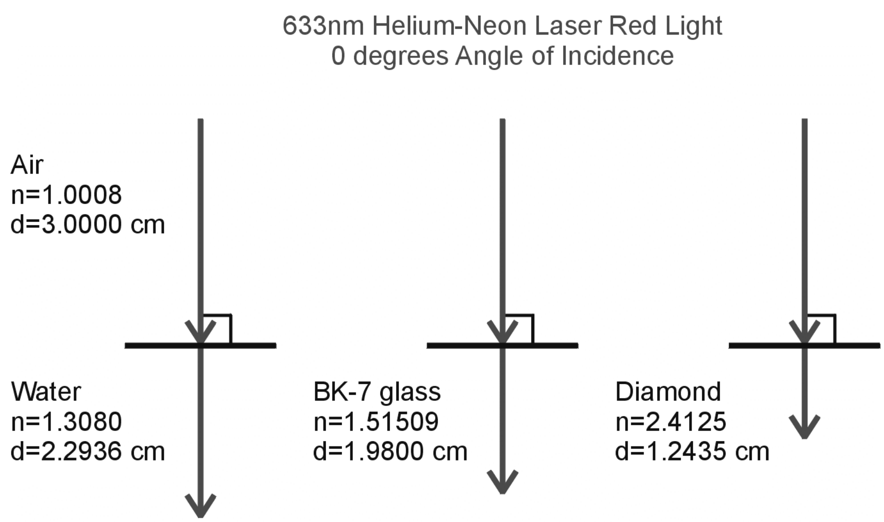

Figure 1: Relative distances traveled in the same amount of time for various refractive index materials.

When the beam is incident at angles other than 0°, bending takes place as the ray slows down due to the higher refractive index. Below are examples of the refraction for the three materials on the previous page, as the angle of incidence increases by 15 ° in each example. (The relative distances traveled in the same length of time are preserved.)

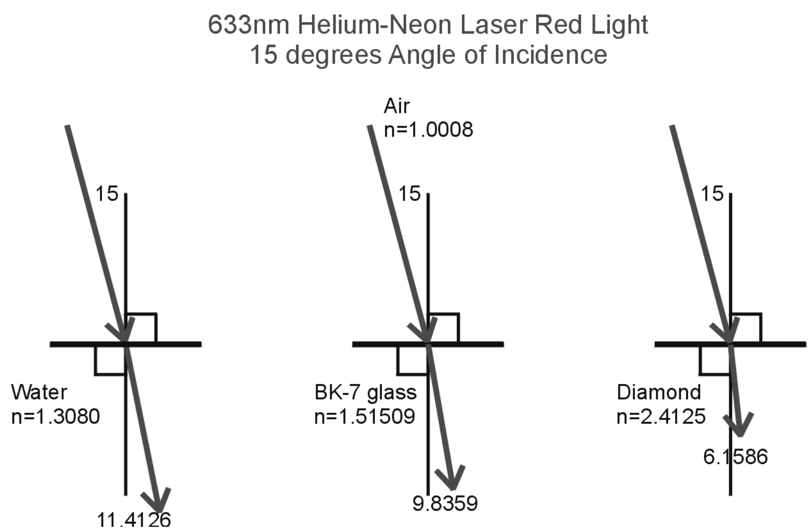

Figure 2: Interior Angles of Refraction for 15° Exterior Angle of Incidence.

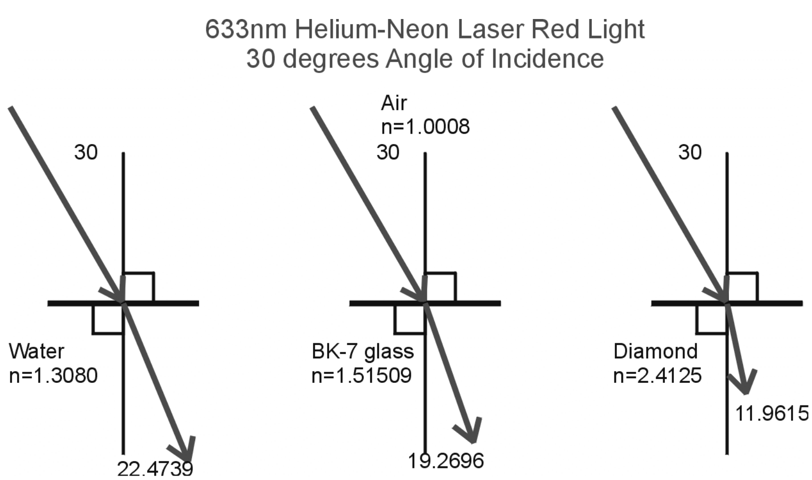

Figure 3: Interior Angles of Refraction for 30° Exterior Angle of Incidence.

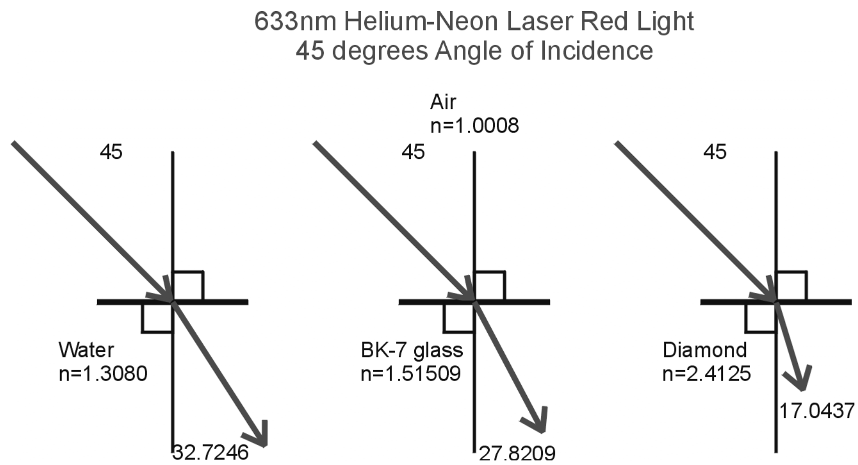

Figure 4: Interior Angles of Refraction for 45° Exterior Angle of Incidence.

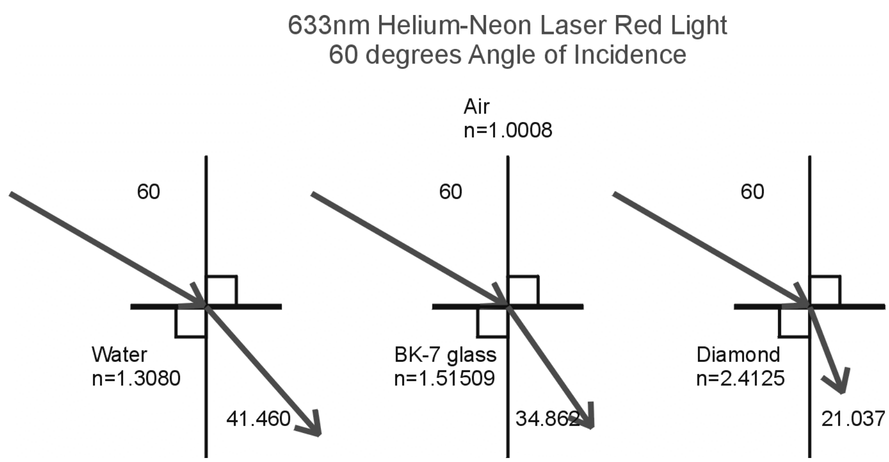

Figure 5: Interior Angles of Refraction for 60° Exterior Angle of Incidence.

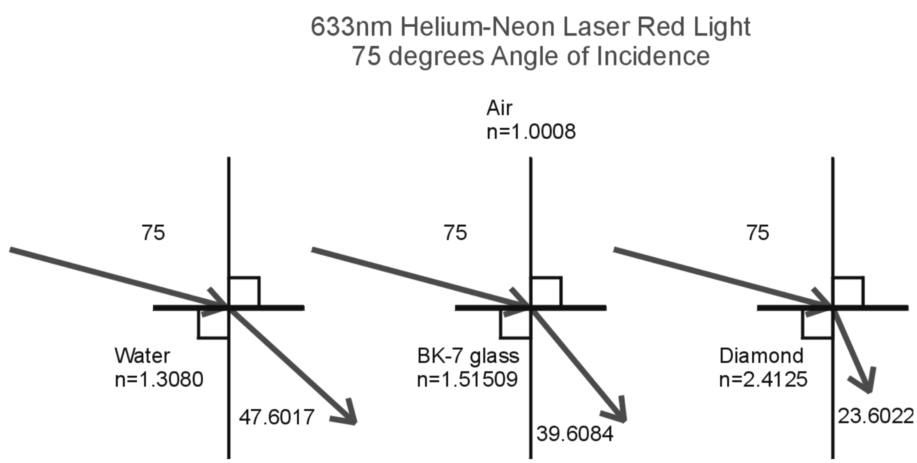

Figure 6: Interior Angles of Refraction for 75° Exterior Angle of Incidence.