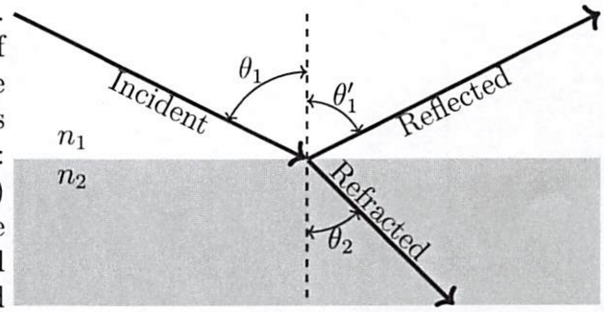
We have previously learned that all electromagnetic waves traveling through vacuum travel at the exact same speed: the speed of light, $c = 3.00 \times 10^8$ m/s. However, if a ray of light enters a material it will typically slow down. We can then define the index of refraction for that material as the ratio of the speed of light in a vacuum to the speed of light in that material: $n = \frac{c}{v}$. The index of refraction of air is very slightly more than one (we will round it to $n_{\text{air}} \approx 1.00$) while for water it is $n_{\text{water}} = 1.33$.

Suppose that a ray of light is traveling in a material with an index of n_1. We will call this the incident ray of light. This light strikes an interface with a second material whose index is n_2. This ray will split into two parts: the reflected ray will bounce (reflect) back into the original material while a portion called the refracted ray will move into the second material and bend (or refract).



We then draw the normal: a line perpendicular (normal) to the interface between the material at the place where the incident ray hits the interface. All angles are measured relative to this normal direction. θ_1 is the angle of incidence, θ_1' is the angle of reflection, and θ_2 is the angle of refraction. The relationship between these angles is:

$$\theta_1' = \theta_1 \qquad\qquad n_1 \sin\theta_1 = n_2 \sin\theta_2 \text{ (Snell's Law)}$$

We see that when light enters a material with a larger index ($n_2 > n_1$) it bends toward the normal ($\theta_2 < \theta_1$) while when light enters a material with a smaller index ($n_2 < n_1$) it bends away from the normal ($\theta_2 > \theta_1$).

When light is moving from a material with a larger index into one with a smaller index ($n_2 > n_1$) it is possible for $\frac{n_1}{n_2}\sin\theta$ to be bigger than 1. In that scenario there can be no angle of refraction that satisfies Snell's Law. In that case the light undergoes total internal reflection: 100% of the light is reflected and none is transmitted. We see that the critical angle is given by $\sin\theta_c = \frac{n_2}{n_1}$ and that total internal reflection will occur when the incident angle exceeds the critical angle, $\theta_1 > \theta_c$.

The speed of light in glass is 2.00×10^8 m/s. (a) what is the index of refraction for this glass? (b) Light traveling through this glass makes a 25° angle with the normal when it passes into air. What is the refracted angle? (c) What is the critical angle before it undergoes total internal reflection?

a) $n = \frac{c}{v} = \frac{3.0\times10^8 \text{ m/s}}{2.0\times10^8 \text{ m/s}} = \boxed{1.50}$

b) $n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad (1.50)\sin 25° = (1.00)\sin\theta_2 \quad \boxed{\theta_2 = 39.3°}$

c) $\theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right) = \sin^{-1}\left(\frac{1.0}{1.5}\right) = \boxed{41.8°}$