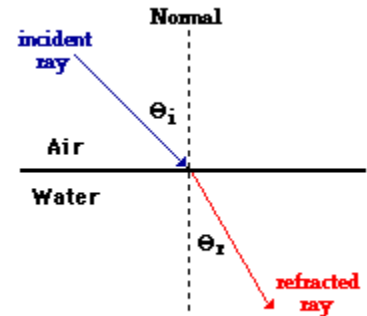


Refraction Of Light:

The diagram to the right shows a light ray undergoing refraction as it passes from air into water. The **incident ray** is a ray that shows the direction that light travels as it approaches the boundary. Similarly, the **refracted ray** is a ray that shows the direction that light travels after it has crossed over the boundary. In the diagram, a normal line is drawn to the surface at the point of incidence. This line is always drawn perpendicular to the boundary. The angle that the incident ray makes with the normal line is referred to as the **angle of incidence**. Similarly, the angle that the refracted ray makes with the normal line is referred to as the **angle of refraction**. The angle of incidence and angle of refraction are denoted by the following symbols:



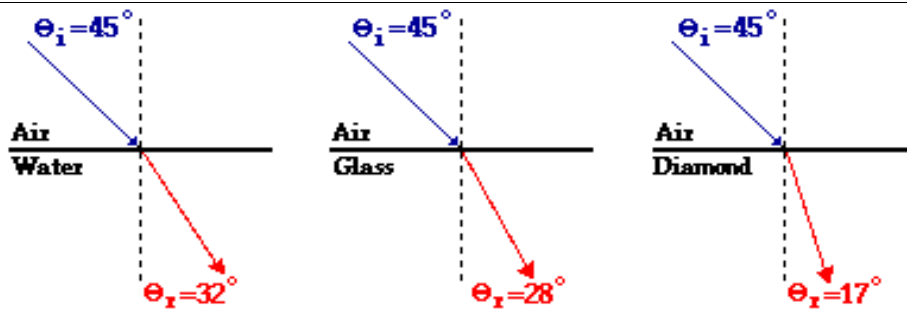
θ_i = angle of incidence

θ_r = angle of refraction

Concept of Refractive index of different medium

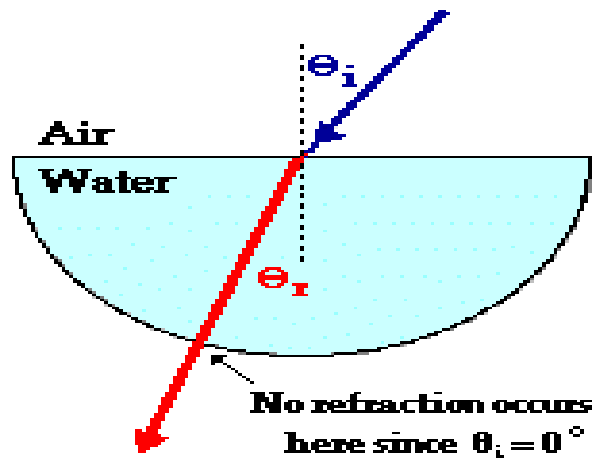
The diagram below depicts a ray of light approaching three different boundaries at an angle of incidence of 45-deg. The refractive medium is different in each case, causing different amounts of refraction due to the different nature of mediums. Normally air is considered as a rarer medium while glass, water, oil and diamond are considered as denser mediums. The speed / velocity of light is different in different mediums.

The angles of refraction are shown on the diagram.



Snell's Law:

Refraction is the bending of the path of a light wave as it passes across the boundary separating two media. Refraction is caused due to the change in velocity of light that experienced by a wave when it changes medium.

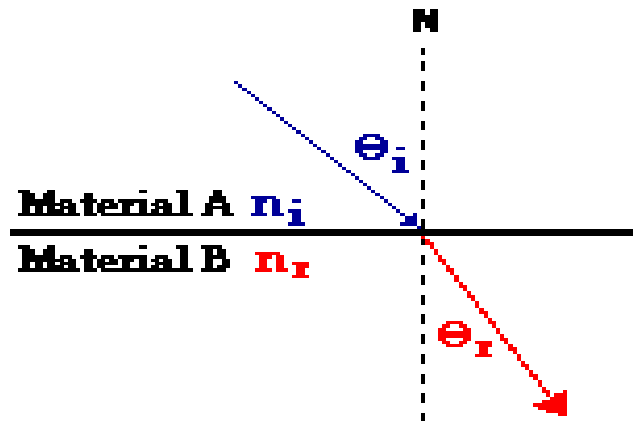


The Mathematics of Refraction

A mathematical equation relating the two angles (angles of incidence and refraction) and the indices of refraction of the two materials on each side of

the boundary, The equation is known as the Snell's Law equation and is expressed as follows.

$$\mu = \frac{\text{Sini}}{\text{Sinr}}$$



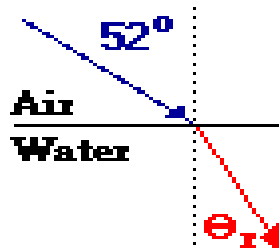
Where,

θ_i = angle of incidence

θ_r = angle of refraction

μ = **refractive index**

Diagram:



Given:

$$n_i = 1.00$$

$$n_r = 1.333$$

$$\theta_i = 52 \text{ degrees}$$

Find:

$$\theta_r = ?$$

Now list the relevant equation (Snell's Law), substitute known values into the equation, and perform the proper algebraic steps to solve for the unknown.

$$n_i * \text{sine}(\theta_i) = n_r * \text{sine}(\theta_r)$$

$$1.00 \times \sin 52 \text{ deg} = 1.333 \times \sin \theta_r$$

$$0.7880 = 1.333 \times \sin \theta_r$$

$$0.591 = \sin \theta_r$$

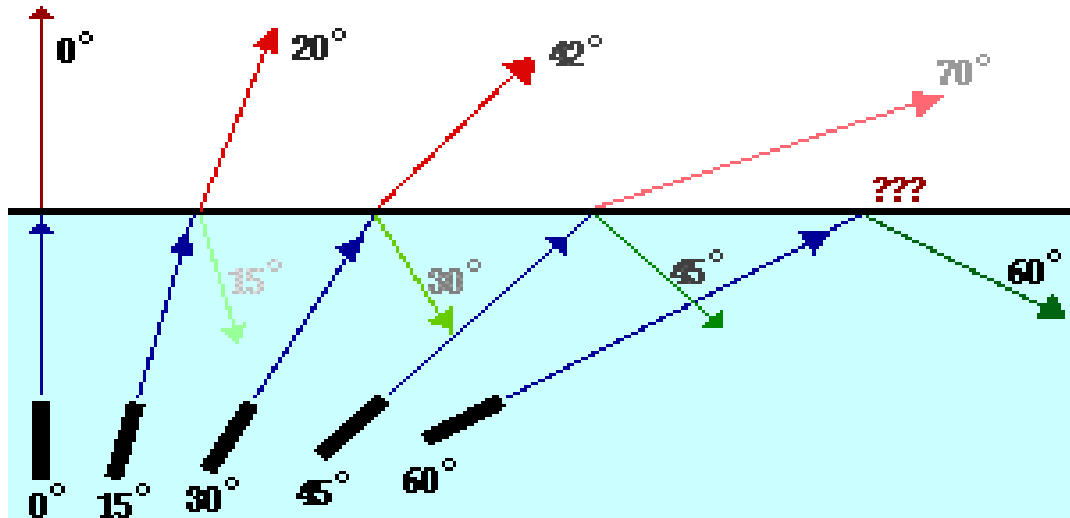
$$\sin^{-1} (0.591) = \theta$$

Total Internal Reflection

The phenomenon observed in this part of the lab is known as total internal reflection. **Total internal reflection**, or **TIR** as it is intimately called, is the reflection of the total amount of incident light at the boundary between two media.

Suppose that a laser beam is submerged in a tank of water and pointed upwards towards water-air boundary. Then suppose that the angle at which the beam is directed upwards is slowly altered, beginning with small angles of incidence and proceeding towards larger and larger angles of incidence. As the angle is increased to greater and greater angles, we would begin to observe less refraction and more reflection. That is, as the angle of incidence is increased, the brightness of the refracted ray decreases and the brightness of the reflected ray increases. Finally, we would observe that the angles of the reflection and refraction are not equal. Since the light waves would refract away from the normal angle of refraction would be greater than the angle of incidence. And if this were the case, the angle of refraction would also be greater than the angle of reflection (since the angles of reflection and incidence are the same). As the angle of incidence is increased, the angle of refraction would eventually reach a 90-degree angle. These principles are depicted in the diagram below.

As the angle of incidence increases from 0 to greater angles ...



- ...the refracted ray becomes dimmer (there is less refraction)**
- ...the reflected ray becomes brighter (there is more reflection)**
- ...the angle of refraction approaches 90 degrees until finally a refracted ray can no longer be seen.**

The maximum possible angle of refraction is 90-deg. If the angle of refraction were greater than 90 deg, then the refracted ray would lie on the incident side of the medium - that's just not possible. So in the case of the laser beam in the water, there is some specific value for the angle of incidence that yields an angle of refraction of 90-deg, **such value of angle of incidence due to which angle of refraction becomes equal to 90 deg is called as critical angle.**

Example of Calculation of critical angle:

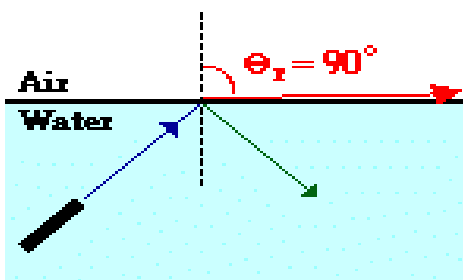
We can obtain that value of critical angle by using Snell's Law by using the following data in which the refractive index of water is 1.33 while the refractive index of air is 1.00, the angle of refraction is 90 deg then according to Snell's Law angle of incidence (Critical angle) would be found to be 48.6 deg.

Two Requirements for Total Internal Reflection

Total internal reflection (TIR) is the phenomenon that involves the reflection of all the incident light off the boundary. TIR only takes place when both of the following two conditions are met:

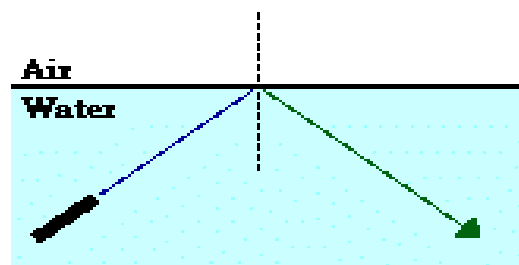
- The light is travelling from denser medium to rarer one.
- The angle of incidence is greater than the critical angle.

Reflection and Refraction



When the angle of incidence equal the critical angle, the angle of refraction is 90-degrees.

Total Internal Reflection



When the angle of incidence is greater than the critical angle, all the light undergoes reflection.