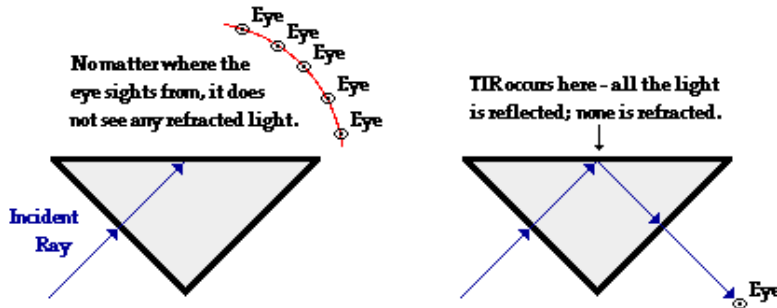


TOTAL INTERNAL REFLECTION

A ray of light entered the face of the triangular block at a right angle to the boundary. This ray of light passes across the boundary without refraction since it was incident along the normal. The ray of light then travels in a straight line through the glass until it reaches the second boundary. Now instead of transmitting across this boundary, all of the light seems to reflect off the boundary and transmit out the opposite face of the isosceles triangle. Why did light not refract through the second face?

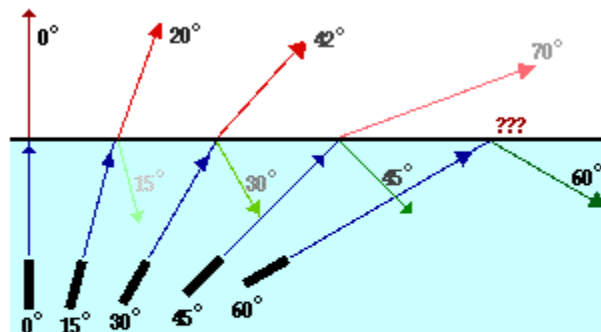
The Discrepant Event - Total Internal Reflection



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.

To understand total internal reflection, we will begin with a thought experiment. Suppose that a laser beam is submerged in a tank of water (don't do this at home) 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. What would be observed in such an experiment? If we understand the principles of boundary behavior, we would expect that we would observe both reflection and refraction. And indeed, that is what is observed (mostly). But that's not the only observation that we could make. We would also observe that the intensity of the reflected and refracted rays do not remain constant. At angle of incidence close to 0 degrees, most of the light energy is transmitted across the boundary and very little of it is reflected. 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 the 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 Critical Angle Derivation

So the critical angle is defined as the angle of incidence that provides an angle of refraction of 90-degrees (maximum possible angle of refraction). Make particular note that the critical angle is an angle of incidence value. For the crown glass-water boundary, the critical angle is 61.0-degrees. The actual value of the critical angle is dependent upon the combination of materials present on each side of the boundary. Let's consider two different media - creatively named medium i (incident medium) and medium r (refractive medium). The critical angle is the θ_i that gives a θ_r value of 90-degrees. If this information is substituted into Snell's Law equation, a generic equation for predicting the critical angle can be derived. The derivation is shown below.

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

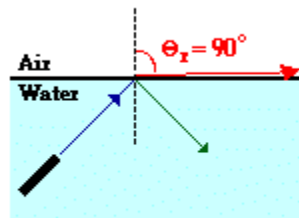
$$n_i \cdot \text{sine}(\theta_{\text{crit}}) = n_r \cdot \text{sine}(90 \text{ degrees})$$

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:

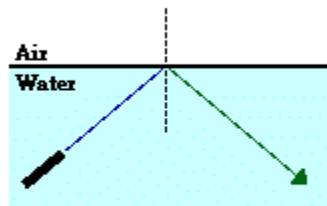
1. the light is in the more dense medium and approaching the less dense medium.
2. the angle of incidence is greater than the so-called critical angle. (typically large angles of incidence)

Reflection and Refraction



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

Total Internal Reflection

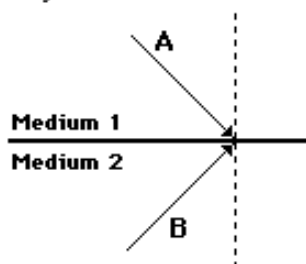


When the angle of incidence is greater than the critical angle, all the light undergoes reflection.

1. For each combination of media, which light ray (A or B) will undergo total internal reflection if the incident angle is gradually increased?

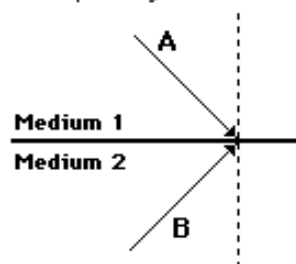
Practice A

The index of refraction is greatest in medium 1.



Practice B

Medium 1 is more optically dense.



2. Calculate the critical angle for the crown glass ($n = 1.52$) & air ($n = 1.0$) boundary.