RAY OPTICS AND OPTICAL INSTRUMENTS

TOTAL INTERNAL REFLECTION

CRITICAL ANGLE AND TOTAL INTERNAL REFLECTION (T.I.R.)

The critical angle is the specific angle formed within a denser medium, at which the angle of refraction in the adjacent rarer medium becomes 90 degrees. Once the angle in the denser medium surpasses the critical angle, an intriguing optical phenomenon occurs—the light ray ceases to refract and, instead, undergoes total internal reflection. During this process, the light ray reflects back into the denser medium, adhering to the laws of reflection. Consequently, the interface between the two mediums mimics the behavior of a flawlessly reflecting mirror. This scenario is illustrated in the accompanying figure.

O = object

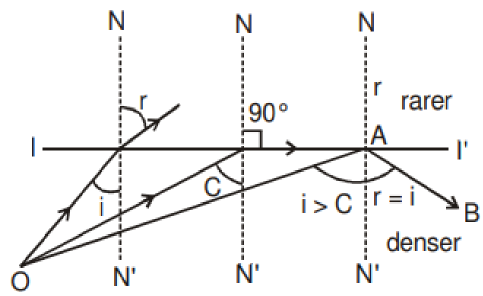
NN′ = Normal to the interface

II′ = Interface

C = Critical angle:

AB = reflected ray due to T.I.R.

When i = C then r = 90°



Conditions of T.I.R.:

(a) Light Incident from Denser Medium:

In this context, light approaches and strikes the interface from a medium characterized as denser. This implies that the incident light is originating from a medium with a higher refractive index. The behavior of light at the interface, including phenomena such as reflection and refraction, is influenced by the optical properties of the denser medium from which the light is emanating. The manner in which light interacts with the interface, particularly during transitions between different media, is fundamental to understanding optical principles and phenomena.

(b) Angle of Incidence Greater than Critical Angle ($i > c$):

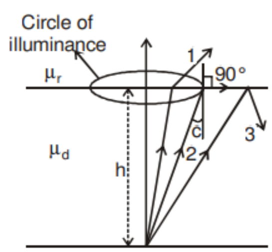
In this scenario, the condition is specified that the angle of incidence (represented by i) should exceed the critical angle (c). The critical angle is a pivotal parameter in optics, and when the angle of incidence surpasses this critical value, it leads to a phenomenon known as total internal reflection.

The illustration depicts a luminous object positioned within a denser medium, at a distance h from an interface demarcating two distinct media characterized by refractive indices denoted as μr and μd.

The subscripts r and d correspond to the terms rarer and denser medium, respectively. This configuration sets the stage for the exploration of optical behaviors and phenomena associated with light traversing between media of differing refractive indices.

In the depicted illustration, Ray 1 impinges upon the surface at an angle below the critical angle (denoted as C) and undergoes refraction in the rarer medium. Ray 2 approaches the surface at the critical angle, skimming the interface. Ray 3 strikes the surface at an angle exceeding the critical angle, resulting in internal reflection. The collection of points where the rays strike at the critical angle forms a circular pattern known as the circle of illuminance. All incident light rays within this circle undergo refraction in the rarer medium.

For an observer situated in the rarer medium, only light emerging from within the circle of illuminance is perceptible. If a circular opaque plate obstructs this circle, preventing light from refracting into the rarer medium, the object becomes invisible from that vantage point. The determination of the radius of the Circle of Illuminance can be readily ascertained.



Example.

Determine the maximum angle attainable within a glass medium, characterized by a refractive index (μ) of 1.5, when a light ray undergoes refraction from glass to a vacuum.

Solution.

1.5 sin C = 1 sin 90°, where C = critical angle

Sin C = 2/3 ⇒C = $\sin^{-1}$ 2/3

Example.

Calculate the angle of refraction within a medium with a refractive index (n) of 2, when light is incident in a vacuum at an angle precisely twice the critical angle.

Solution.

Since the incident light is in rarer medium. Total Internal Reflection cannot take place.

$$\therefore C = \sin^{-1}\frac{1}{\mu} = 30^\circ \Rightarrow \quad \therefore \ i = 2c = 60^\circ$$

Applying Snell's Law. 1 sin 60° = 2 sin r

$$\sin r = \frac{\sqrt{3}}{4} \Rightarrow \ r = \sin^{-1}\left(\frac{\sqrt{3}}{4}\right)$$