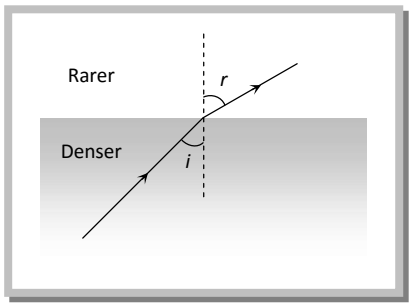
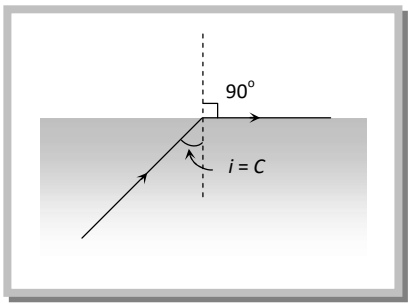
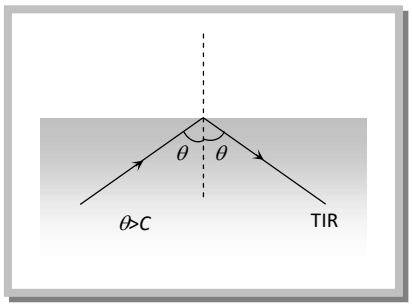
Total Internal Reflection.

When a ray of light goes from denser to rarer medium it bends away from the normal and as the angle of incidence in denser medium increases, the angle of refraction in rarer medium also increases and at a certain angle, angle of refraction becomes 90o, this angle of incidence is called critical angle (C).

When Angle of incidence exceeds the critical angle than light ray comes back in to the same medium after reflection from interface. This phenomenon is called Total internal reflection (TIR).



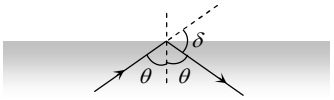




Important formula $\mu = \dfrac{1}{\sin C} = \text{cosec}\ C$; where $\mu \rightarrow {}_{\text{Rerer}}\mu_{\text{Denser}}$

Note: When a light ray travels from denser to rarer medium, then deviation of the ray is $\delta = \pi - 2\theta \Rightarrow \delta \rightarrow \max.$ when $\theta \rightarrow \min. = C$

i.e. $\delta_{\max} = (\pi - 2C);$ C → critical angle



(1) Dependence of critical angle

(i) Color of light (or wavelength of light): Critical angle depends upon wavelength as

$\lambda \propto \dfrac{1}{\mu} \propto \sin C$

(a) $\lambda_R > \lambda_V \Rightarrow C_R > C_V$

(b) Sin C $= \frac{1}{{}_R\mu_D} = \frac{\mu_R}{\mu_D} = \frac{\lambda_D}{\lambda_R} = \frac{v_D}{v_R}$ (for two media) (c) For TIR from boundary of two media $i > \sin^{-1}\frac{\mu_R}{\mu_D}$

(ii) Nature of the pair of media: Greater the refractive index lesser will be the critical angle.

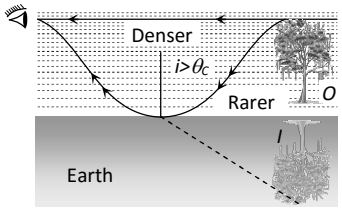
(a) For (glass- air) pair $\rightarrow C_{\text{glass}} = 42^o$ (b) For (water-air) pair $\rightarrow C_{\text{water}} = 49^o$

(c) For (diamond-air) pair $\rightarrow C_{\text{diamond}} = 24^o$

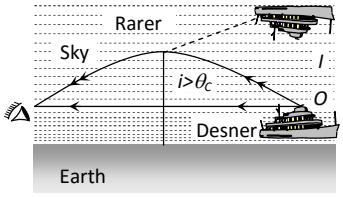
(iii) Temperature: With temperature rise refractive index of the material decreases therefore critical angle increases.

(2) Examples of total internal reflection (TIR)

(i)



Mirage : An optical illusion in deserts

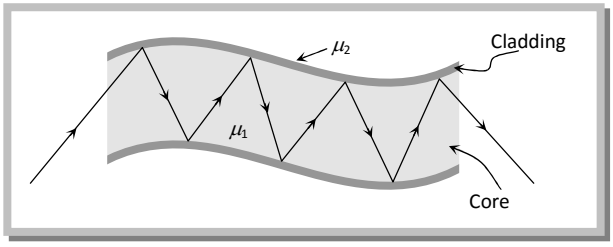


Looming : An optical illusion in cold countries

(ii) Brilliance of diamond: Due to repeated internal reflections diamond sparkles.

(iii) Optical fiber: Optical fibers consist of many long high quality composite glass/quartz fibers. Each fiber consists of a core and cladding. The refractive index of the material of the core (μ1) is higher than that of the cladding (μ2).

When the light is incident on one end of the fiber at a small angle, the light passes inside, undergoes repeated total internal reflections along the fiber and finally comes out. The angle of incidence is always larger than the critical angle of the core material with respect to its cladding. Even if the fiber is bent, the light can easily travel through along the fiber

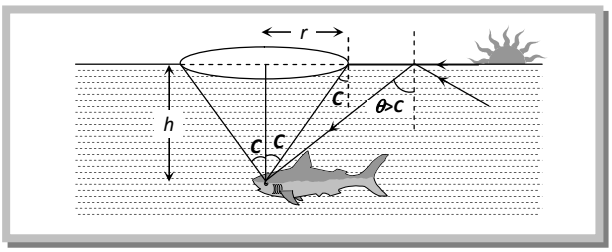


A bundle of optical fibers can be used as a 'light pipe' in medical and optical examination. It can also be used for optical signal transmission. Optical fibers have also been used for transmitting and receiving electrical signals which

are converted to light by suitable transducers.

(iv) Field of vision of fish (or swimmer): A fish (diver) inside the water can see the whole world through a cone with.

(a) Apex angle $= 2C = 98^o$

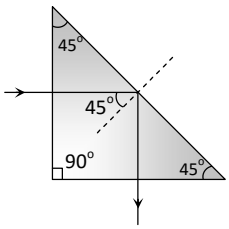


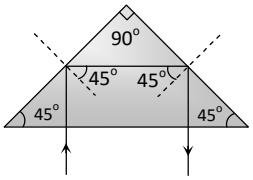
(b) Radius of base $r = h\tan C = \dfrac{h}{\sqrt{\mu^2 - 1}}$

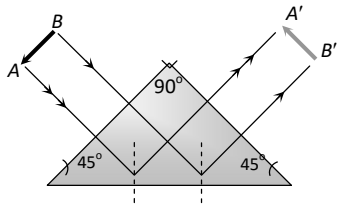
(c) Area of base A $= \dfrac{\pi h^2}{(\mu^2 - 1)}$

Note: For water $\mu = \dfrac{4}{3}$ so $r = \dfrac{3h}{\sqrt{7}}$ and $A = \dfrac{9\pi h^2}{7}$.

(v) Porro prism: A right angled isosceles prism, which is used in periscopes or binoculars. It is used to deviate light rays through 90^o and 180^o and also to erect the image.







Concepts

In case of refraction of light frequency (and hence color) and phase do not change (while wavelength and velocity will change).

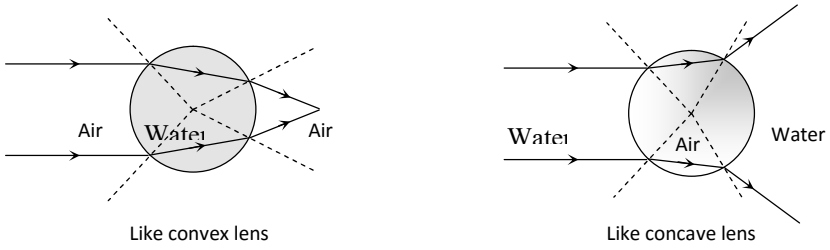
In the refraction intensity of incident light decreases at it goes from one medium to another medium.

A transparent solid is invisible in a liquid of same refractive index (Because of No refraction).

When a glass slab is kept over various colored letters and seen from the top, the violet color letters

appears closer (Because $\lambda_v < \lambda_R$ so $\mu_V > \mu_R$ and from $\mu = \frac{\lambda}{\lambda'}$ if μ increases then h' decreases i.e. Letter appears to be closer)

Water drop in air and air bubble in water behaves as a lens.



Like convex lens

Like concave lens