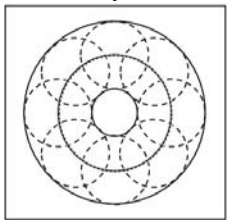
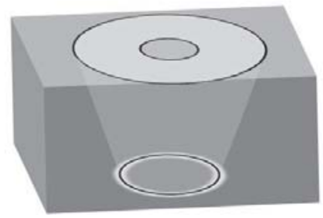
REFRACTION OF LIGHT THROUGH MULTIPLE MEDIA

Refraction:- Bright Patch due to Ring type Light Source

Let's view each point on the ring-shaped light source as an individual point source of light. If there is no total internal reflection of the ray, an observer positioned on the water surface can perceive this point source of light. Consequently, it becomes visible within a circular area, the radius of which is determined by the critical angle. This circular area is depicted in the nearby figure.





The brightness of the central spot can vary, contingent upon the gap between the circles, which is influenced by the dimensions of the light source. If the radius of the circle formed on the surface by the point source is greater than or equal to the radius of the ring source, then a fully illuminated circular patch will be produced.

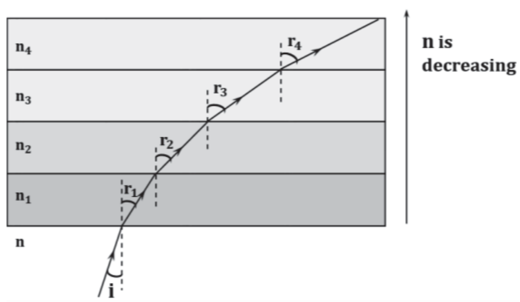
Refraction of Light Through Multiple Media

Here, the rays get refracted at each interface. From Snell's law, we can write as follows:

First refraction: $n\sin(i_i) = n_1\sin(r_1)$

Second refraction: $n_1\sin(r_1) = n_2\sin(r_2)$

Final refraction: $n_4\sin(r_4) = n_{final}\sin(r_{final})$



Thus, for any number of mediums in between, we get:

$$n_{initial}\sin(i_{initial}) = n_{final}\sin(r_{final})$$

Valid only when there is no TIR of light

Ex. If a ray of light goes through multiple media as shown, find the net angle of deviation.

Sol. We have, $n_{initial}\sin(i_{initial}) = n_{final}\sin(r_{final})$

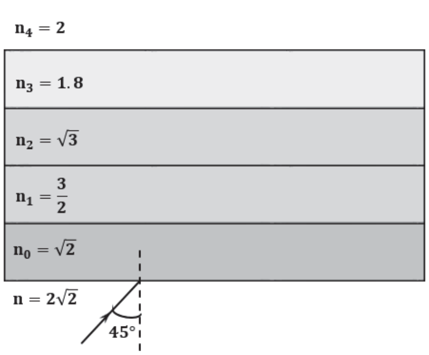
This formula applies exclusively under the condition of no total internal reflection (TIR) of light. However, in this particular case, TIR is present.

The ray will get reflected from the first slab. Here, on first slab:

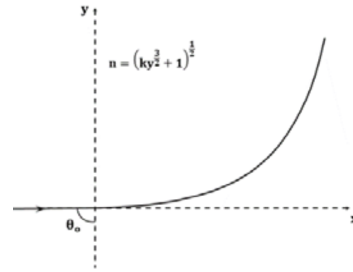
$$n\sin(i) = n_0\sin(r_1)$$

$$2\sqrt{2}\sin(45°) = \sqrt{2}\sin(r_1)$$

$$r_1 = \sin^{-1}(\sqrt{2}) = 135° \text{ Thus, } \delta = r_1 - i = 90°$$



Ex. If a ray of light goes through a medium having refractive index given by $n = (ky^{\frac{3}{2}} + 1)^{\frac{1}{2}}$ at an angle of incidence, $\theta_o \approx 90°$ as shown, find the equation of the path followed by the light ray in the medium if $K = 1$.

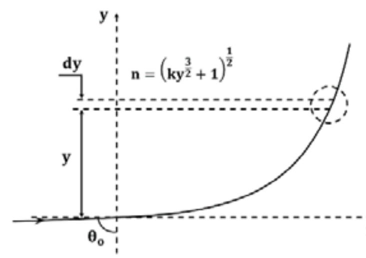


Sol. Refractive index increases with y as shown in figure. Let a strip of medium at y having thickness dy. Ray is incident at $\theta_o \approx 90°$ i.e., at grazing angle. We have,

$$n_i \cdot \sin i = n_f \sin r_f$$

$$1 \cdot \sin 90 = (y^{3/2} + 1)^{\frac{1}{2}} \cdot \sin\theta.$$

$$\sin\theta = \frac{1}{(y^{3/2}+1)^{1/2}} = \frac{p}{H} \cot\theta = \frac{B}{p}.$$



From figure, slope of the trajectory

$$\tan(90 - \theta) = \int \text{ lope}$$

$$= dy/dx = \cot\theta$$

We have, $$\cot\theta = \frac{B}{p}$$

$$\cot\theta = \frac{\sqrt{((y^{3/2}+1)^{1/2})^2 - 1^2}}{1} = \frac{\sqrt{y^{3/2}+1-x}}{1} = y^{3/4}$$

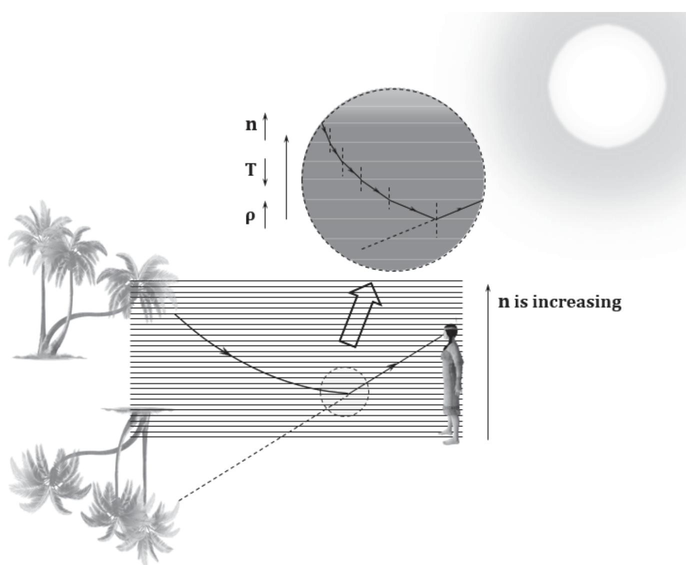
$$\frac{dy}{dx} = y^{3/4}$$

$$\int_0^y y^{-3/4} dy = \int_0^x dx$$

$$4y^{1/4} = x$$

Mirage Formation

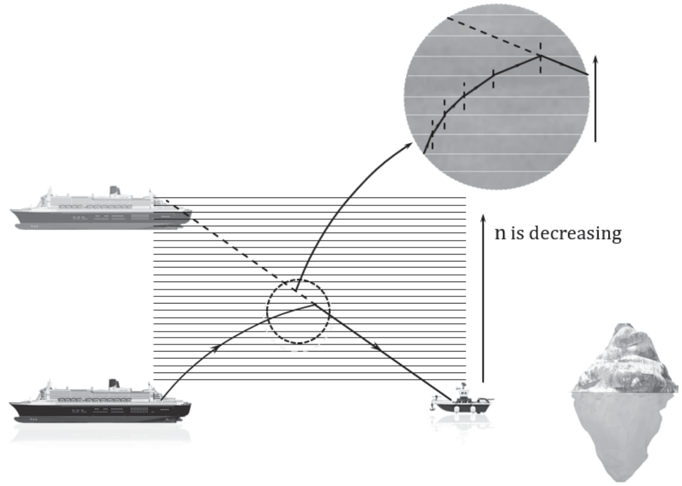
When temperatures soar, the air near the ground warms up. As altitude increases, temperatures tend to drop. This variation in temperature as altitude changes affects the air's density and, consequently, its refractive index. Consequently, when a ray encounters a boundary between air layers at a certain altitude, it undergoes refraction. As one descends from a specific altitude towards the ground, the density decreases, causing refracted rays to diverge from the normal path. At a specific altitude, total internal refraction occurs, making the layer appear like a mirror. This is the phenomenon responsible for the appearance of water on roads during hot weather and the inverted appearance of trees in desert landscapes. This optical illusion is commonly known as a "Mirage."



Looming Formation

When temperatures plummet, the air layer near the ocean's surface cools down. As altitude increases, temperatures tend to rise. This temperature shift with height causes a change in density and subsequently alters the refractive index of the air. Consequently, when a ray from the surface encounters a boundary between air layers, it undergoes refraction.

As one ascends from a certain height towards the water, the density increases, causing refracted rays to deviate from the normal path. At a specific altitude, total internal refraction occurs, creating a mirrored effect within the layer. This is the phenomenon responsible for the optical illusion where ships appear to float inverted in the air in cold regions. This phenomenon is known as "looming."



Applications Of TIR (Diamond)

Sparkling of Diamonds

Critical angle for Diamond to air interface: 24.4°

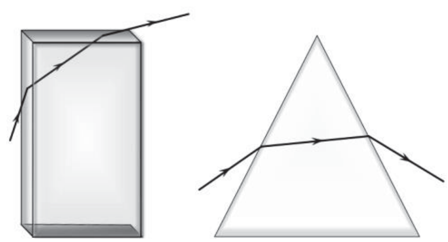
The brilliance of sparkling enhances the allure of the diamond.

The critical angle at the interface between diamond and air is exceedingly minimal, heightening the probability of total internal reflection (TIR).

The diamond's surface is meticulously crafted to allow rays to emanate from it selectively, following numerous reflections within. These recurrent instances of TIR within the diamond contribute to its dazzling sparkle.

Prism

The concept of a prism comes into play when a light ray traverses through two inclined plane surfaces within a medium.



The concept of a prism can be applied to various geometrical objects when their surfaces are inclined, as depicted in the figure.

Angle of Prism

Prism Angle: This refers to the angle formed between the two inclined surfaces through which the refracted ray passes. It is also known as the refracting angle of the prism.