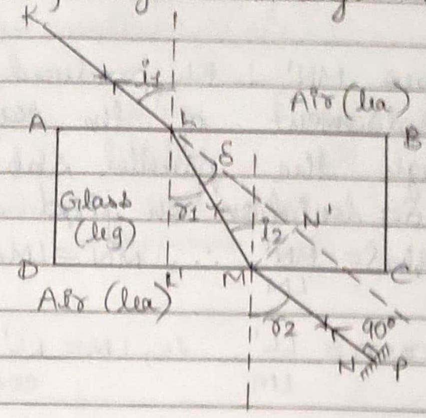
Refraction of light through a rectangular glass sla



In going from a rarer medium to a denser medium, the ray bends towards the normal, and in going from a denser to a rarer medium, the ray bends away from the norm

$$\mu a \times \sin i_1 = \mu g \times \sin r_1$$

or

$$\frac{\sin i_1}{\sin r_1} = \frac{\mu g}{\mu a} = {}^{a}\mu g \quad \text{—(i)}$$

$$\mu g \times \sin i_2 = \mu a \times \sin r_2$$

$$\frac{\mu a}{\mu g} = \frac{\sin i_2}{\sin r_2} = {}^{g}\mu a \quad \text{—(ii)}$$

According to the principle of reversibility of light, when final path of a ray of light after any number of reflections & refractions is reversed, the ray retraces its entire pat

$$\frac{\mu g}{\mu a} = \frac{\sin r_2}{\sin i_2} = {}^{a}\mu g \quad \text{—(iii)}$$

$$\frac{\sin i_2}{\sin r_2} \times \frac{\sin r_2}{\sin i_2} = {}^{g}\mu a \times {}^{a}\mu g = 1$$

i.e, $\boxed{{}^{a}\mu g = \frac{1}{{}^{g}\mu a}}$

Expression for lateral displacement.

From M, draw MN' ⊥ KL produced.

∴ lateral displacement of the ray on passing through the parallel slab = MN'

Let ∠MLN' = δ = deviation on first refraction.

In $\Delta LMN'$; $\sin\delta = \frac{MN'}{LM}$ ∴ $MN' = LM \sin\delta$

In $\Delta LL'M$; $\cos r_1 = \frac{LL'}{LM}$ i.e., $LM = \frac{LL'}{\cos r_1} = \frac{t}{\cos r_1}$

$t = LL'$ = thickness of glass slab.

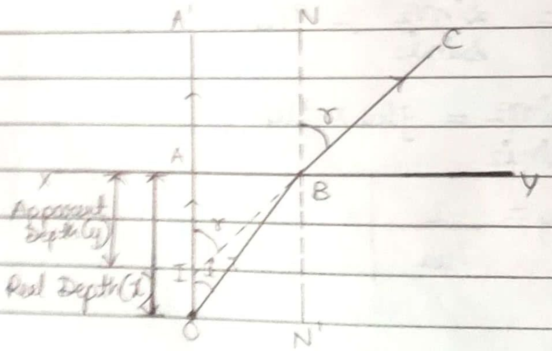
$$MN' = \frac{t}{\cos r_1} \sin\delta$$

or $\boxed{MN' = \frac{t \sin(i_1 - r_1)}{\cos r_1}}$

Reflection involves change in the path of light without any change in medium; whereas refraction involves change in the path of light on change in the medium.

Real Depth and Apparent Depth Of A Tank.

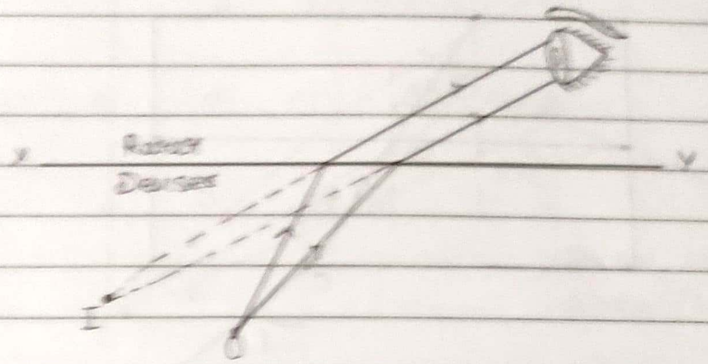
A water tank appears shallower, i.e., less deep than what is actually is. This is on account of refraction of light.



As light is travelling from denser medium (water) to rarer medium (air).

$$^{a}\mu_{w} = \frac{\sin r}{\sin i} = \frac{AB}{IB} \times \frac{OB}{AB} = \frac{OB}{IB}$$

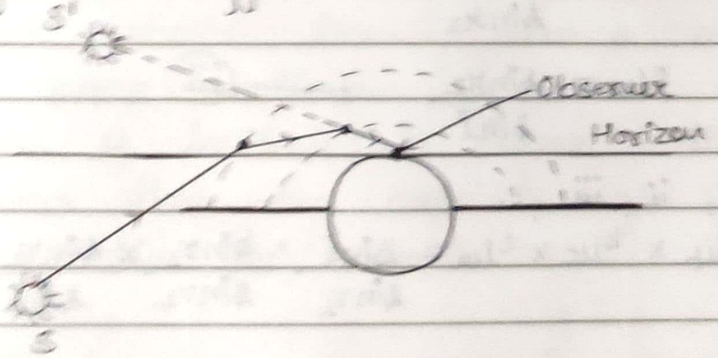
$$\boxed{^{a}\mu_{w} = \frac{\text{real depth}}{\text{apparent depth}} = \frac{x}{y}}$$



Here; $y = \frac{x}{^{a}\mu_{w}} = \frac{x}{4/3} = (3/4)x$

i.e., apparent depth is only (3/4)th of the real depth of the tank of water.

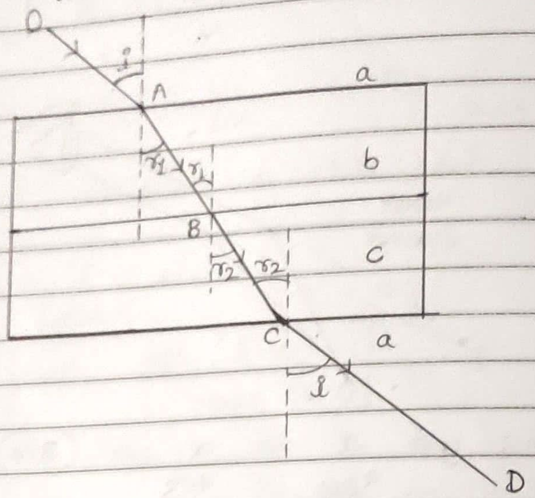
Refraction Effects At Sun rise and Sunset.



The sun is visible to us before actual sun and after actual sunset. This is due to atmospheric refraction of light.

This time difference is of the order of 2 minutes each. Hence the day becomes longer by about 4 minutes due to refraction effects.

Refraction Of Light Through A Compound Plate.



According to Snell's law,

$$^{a}\mu_{b} = \frac{\sin i}{\sin r_1} \quad \text{——} \quad (i)$$

$$^{b}\mu_{c} = \frac{\sin r_1}{\sin r_2} \quad \text{——} \quad (ii)$$

$$^{c}\mu_{a} = \frac{\sin r_2}{\sin i} \quad \text{——} \quad (iii)$$

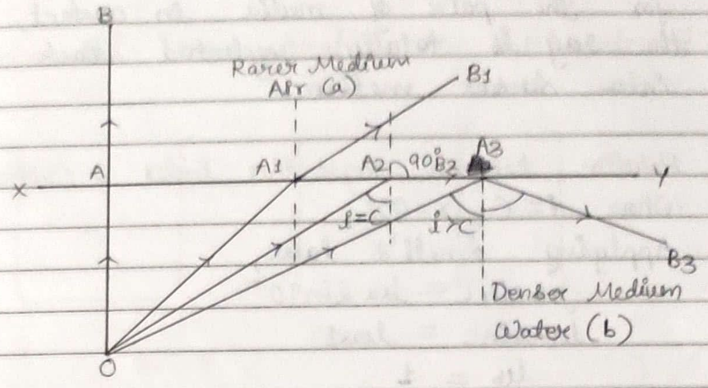
Multiply i, ii, iii ;

$$^{a}\mu_{b} \times {^{b}\mu_{c}} \times {^{c}\mu_{a}} = \frac{\sin i}{\sin r_1} \times \frac{\sin r_1}{\sin r_2} \times \frac{\sin r_2}{\sin i} = 1$$

$$\boxed{^{a}\mu_{b} \times {^{b}\mu_{c}} = \frac{1}{^{c}\mu_{a}} = {^{a}\mu_{c}}}$$

Note that in passing through a glass plate obliquely, a ray of light neither converges nor diverges, but is displaced parallel to itself i.e., it undergoes lateral displacement.

Total Internal Reflection Of Light.



Total internal reflection is the phenomenon of reflection of light into a denser medium from an interface of this denser medium & a rarer medium.

Two essential conditions for total internal reflection are:-

i> Light should travel from a denser medium to a rarer medium.

ii> Angle of incidence in denser medium should be greater than the critical angle for the pair of media in contact.

Critical angle for a pair of media in contact as the angle of incidence in the denser medium corresponding to which angle of refraction in the rarer medium is 90°.

It is represented by C and its value depends on the nature of media in contact.

When a ray of light travelling from an optically denser medium to an optically rarer medium is incident at an angle greater than the critical angle for the pair of media in contact, the ray is totally reflected back into denser medium.

Relation between Refractive index & Critical angle

When $i = C$, $r = 90°$,

Applying Snell's law,

$$\mu_b \sin C = \mu_a \sin 90°$$

$$\mu_b \times \sin C = \mu_a \times 1$$

$$\frac{\mu_b}{\mu_a} = \frac{1}{\sin C}$$

$$\boxed{{}^a\mu_b = \frac{1}{\sin C}}$$

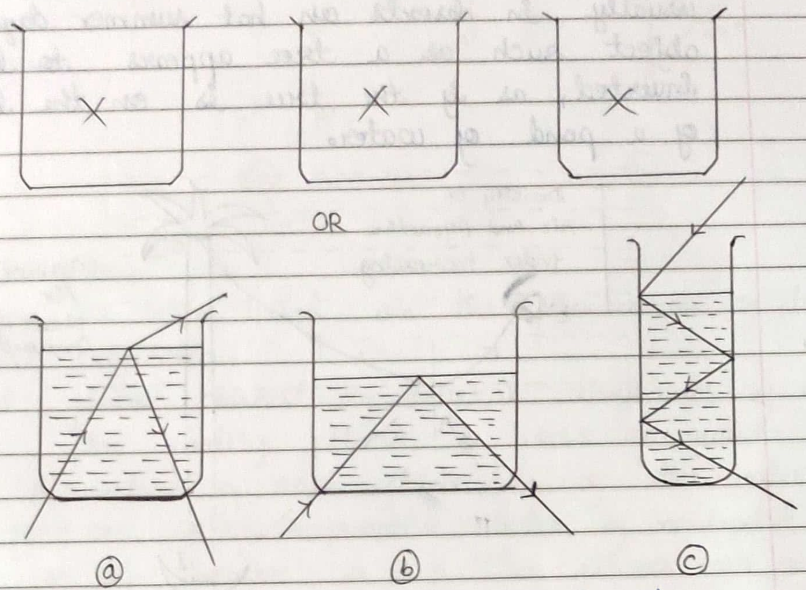
Critical angle for the same pair of media in contact will be different for different colours.

Refractive index μ and critical angle C for some media.

	Media	μ of medium w.r.t. air	Critical angle C
1>	Water	1.33	48.75°
2>	Crown glass	1.52	41.14°
3>	Dense flint glass	1.65	37.30°
4>	Diamond	2.42	24.40°

Remember that for total internal reflection, light must travel from a denser medium to a rarer medium and angle of incidence of light in denser medium must atleast be equal to or greater than the critical angle for the pair of media in contact.

Experimental Demonstration Of Total Internal Reflection.



Laser pointer experiment

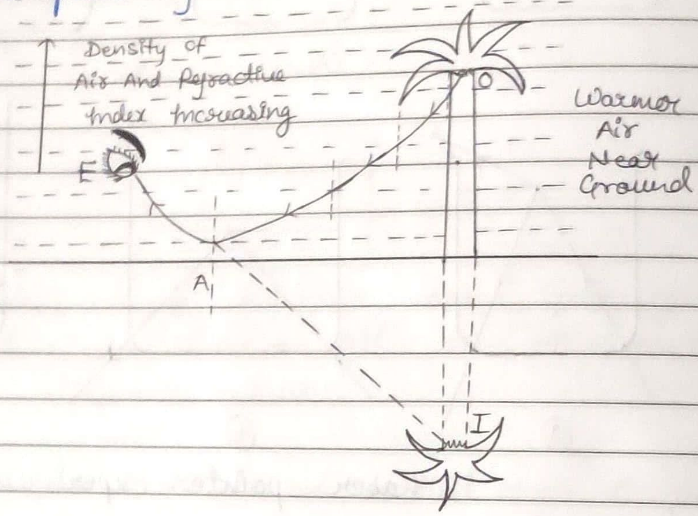
Some Applications Of Total Internal Reflection.

1> The brilliance of diamond.

The brilliance of diamond is due to total internal reflection of light. μ for diamond is 2.42, so that critical angle for diamond air interface as calculated is 24.4°. The diamond is ~~to~~ cut suitably so that light entering the diamond from any face falls at an angle greater than 24.4°. Therefore, it suffers multiple total internal reflections at various faces, and remains within the diamond, failing to come out. Hence, the diamond sparkles.

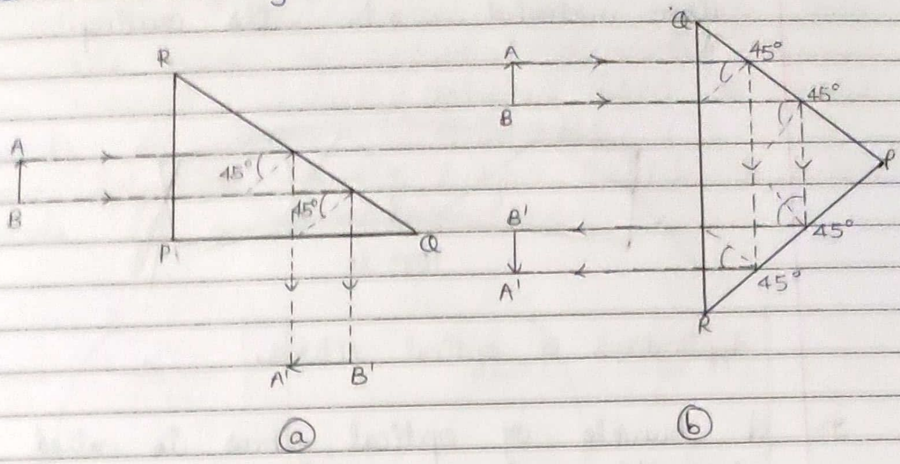
2. Mirage.

Mirage is an optical illusion which occurs usually in deserts on hot summer days. The object such as a tree appears to be inverted, as if the tree is on the bank of a pond of water.



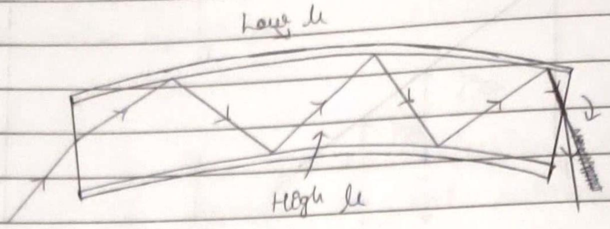
3. Totally reflecting glass prisms.

Totally reflecting glass prisms are right angled isosceles prisms which turn the light through 90° or 180°. They are based on the phenomena of total internal reflection of light. μ for glass is 1.5. so that critical angle for glass-air interface is 42° In totally reflecting glass prisms, angle of incidence is made 45° (>C). Hence, light suffers total internal reflection.



4> Optical fibres.
These are also based on the phenomenon of total internal reflection.
Optical fibres consist of several thousands of very long fine quality fibres of glass or quartz. The diameter of each fibre is of the order of 10^{-4} cm with refractive index of material being of the order of 1.5. The fibres are coated with a thin layer of material of lower refractive index of the order of 1.48.
Light incident on one end of the fibre at a small angle enters the fibre after refraction and undergoes repeated total internal reflections inside the fibre. It finally comes out of the fibre at the other end, even if the fibre is bent or twisted in any form. And there is almost no loss of light through the sides of the fibre.

The only condition is that angle of incidence of light must be greater than the critical angle for the fibre material w.r.t. its coating.



Applications of optical fibres.

1> A bundle of optical fibres is called light pipe, this pipe can transmit an image. Since the pipe is flexible, it can be twisted in any desired manner. Hence, it is used in medical and optical exami-nation of even the inaccessible parts of human body, e.g., in endoscopy.

2> Optical fibres are used in transmission and reception of electrical signals by converting them first into light signals.

3> Optical fibres are used in telephone and other transmitting cables. Each fibre can carry upto 2000 telephone messages without much loss of intensity.