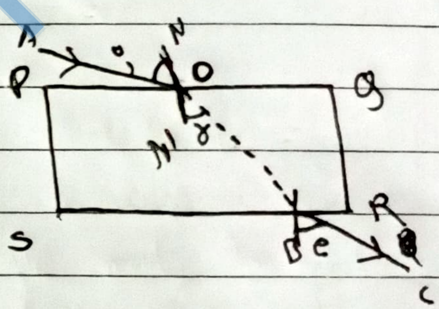
Refraction at plane Surface

- Refraction of light

when a light travels in a One medium it always follow a straight path but, when it moves from one medium to another, it's path changes.
The phenomenon of bending of light when is travels from one medium to another medium is is called refraction of light.
During refraction of light the velocity & wavelength of a light changes but frequency and energy of light remains constant.

- Refraction at plane surface



OA = Incident Ray
OB = Refracted Ray
BC = Emergent Ray
NN' = Normal Ray
$\angle i$ = Angle of incident
$\angle r$ = angle of reflection
$\angle e$ = angle of emergent

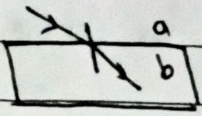
- Principle of /or law of reflection

(I) The Incident ray, reflected ray and normal ray at the point of incidence alway lie on same plane.

II ~~angle~~ ~~a~~ when a ray of light passes through rarer to denser meduim it bends to-wards the normal while the ray of light passing through denser medium to rarer, it bends away from normal

III The ratio of Sin of the angle of incident to sin of angle of reflection is always constant called refractive index $\mu = \frac{\sin i}{\sin r}$

$$\mu = \frac{\sin i}{\sin r}$$

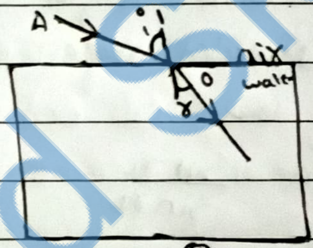


Refractive index of b with a

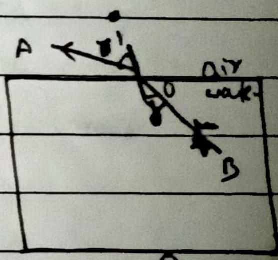
⇒ The refrective index of a malerial is independent of angle of incidience and intensity of light but depends on nature of medium, temperature, wavelenth of light.

Principle of Reversibility.

It states that "if the final path of the ray of light is reversed then ray of light trace (travel) the same path



(a)



(b)

Suppose a ray of light AO is incidint with the angle of incidint (i) and got refracted with refracted with angle of reflection (r) as shown in figure

from Snell's law

$$_{air}\mu_{water} = \frac{\sin i}{\sin r}$$

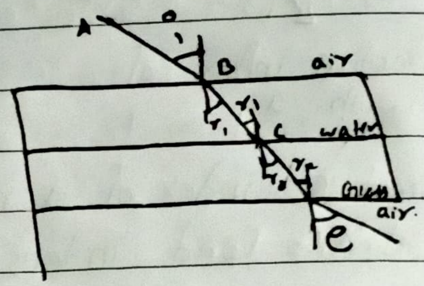
$$_a\mu_w = \frac{\sin i}{\sin r} \quad \text{--- (1)}$$

If the refrected ray OB is reversed to BO as shown in figure the ray of light retrace same intial path OA as before this is called principle of reversibility so, BO is now incidint ray and with the angle of incidence (r) & got refracted with angle of refraction i, from Snell's law

$$_{water}\mu_{air} = \frac{\sin r}{\sin i} \quad \text{--- (1)}$$

$$_a\mu_w \times {}_w\mu_a = \frac{\sin i}{\sin r} \times \frac{\sin r}{\sin i} \qquad _a\mu_w = \frac{1}{_w\mu_a}$$

refrective index for more than two medium



Supose a ray of light AB inciden on a surface of water from air.

Here, $\angle i$ = incidient angle

$\angle r_1$ = reflected angle

from Snell's law

$$_a\mu_w = \frac{\sin i}{\sin r_1}$$

while passing from water to glass

$\angle r_1$ = Incident angle ~~BC~~ made by BC

$\angle r_2$ = Reflected angle made along normal

from Snell's law

$$_w\mu_a = \frac{\sin r_1}{\sin r_2}$$

while passing from glass to air

$\angle r_2$ = ~~Reflecte~~ incident angle mady be Incidence ray

$\angle e$ = angle of emergence

from Snell's law

$$_g\mu_a = \frac{\sin r_2}{\sin e}$$

now,

$$_a\mu_w \times {_w\mu_g} \times {_g\mu_a} = \frac{\sin i}{\cancel{\sin r_1}} \times \frac{\cancel{\sin r_1}}{\cancel{\sin r_2}} \times \frac{\cancel{\sin r_2}}{\sin e}$$

$$_a\mu_w \times {_w\mu_g} \times {_g\mu_a} = \frac{\sin i}{\sin e}$$

$$_a\mu_w \times {_w\mu_g} \times {_g\mu_a} = 1$$

$$_w\mu_g = \frac{1}{_a\mu_w \times {_g\mu_a}}$$

$$_w\mu_g = \frac{_a\mu_g}{_a\mu_w}$$

P b P
n n b

Lateral Shift

① The ray of light incident on the glass slab, the emergent ray will be parallel to the incident ray. the perpendicular distance between the direction of incident ray with the emergent ray is called lateral shift

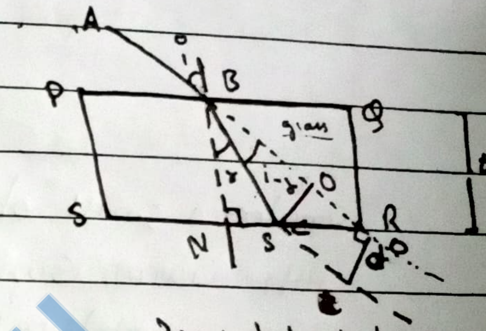


fig: lateral shift

let us consider a glass slab PQRS with the thickness (t) as shown in figure Suppose a ray light AB is incident with the angle of incidence $\angle i$ and refracted along the path BC with the angle of refraction(r) and ultimately it emerges by the path CD which is parallel to direction of incident ray AB. now,

let us draw a perpendicular from C to O which is lateral shift given by the glass slab.

In ΔBOC

$\angle CBO = i - r$

$\sin(i-r) = \frac{CO}{BC} = \frac{d}{BC}$

$\therefore BC \sin(i-r) = d$ ...(i)

In ΔBNC

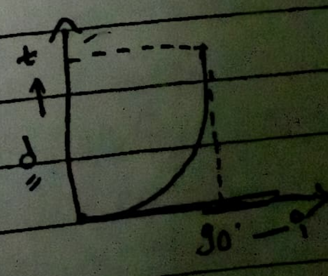
$\cos r = \frac{BN}{BC}$

$BC = \frac{t}{\cos r}$ ...

Substituting the value of BC in eq^n ①

$$d = \frac{t \sin(i-r)}{\cos r}$$

which is the required expression for lateral shift due to a glass slab. if we plot graph between lateral shift and angle of incidence, we get the :-



Special case :-

when $i = 90$

$d = \frac{t \sin(90-r)}{\cos r} = \frac{t \cos r}{\cos r} = t$

Real depth or Apparent depth

Consider a small object O at a bottom of a beaker with water. Suppose a light ray on passes perpendicularly on the surface of water MN and ray OP bends at P and passes along PQ. Here, the two refracted rays AB And PQ appear to come from a same point O. The depth O. The depth AO is real depth of the object and depth AO is apparent depth

In $\triangle$ OAD

$$\sin i = \frac{AP}{OP} \quad \text{--- (I)}$$

In $\triangle$ O'AP, $\sin r = \frac{AP}{O'P}$ --- (II)

Dividing eq^n (I) & (II)

$$\frac{\sin i}{\sin r} = \frac{AP}{OP} \times \frac{O'P}{AP} = \frac{O'P}{OP}$$

Since the value of i and r is very then $O'P \approx O'A$ and $OP \approx OA$,

or $\frac{\sin i}{\sin r} = \frac{O'A}{OA}$ --- (III)

Since, light passes from the denser medium to the rare medium

$$\frac{1}{a\mu_w} = \frac{\sin i}{\sin r} \text{ and hence, } a\mu_w = \frac{\sin r}{\sin i} \text{ --- (IV)}$$

Equating eq^n iii & iv

$$a\mu_w = \frac{OA}{O'A}$$

or $$a\mu_w = \frac{\text{Real depth}}{\text{Apparent depth}}$$

What is the apparent position of an object below rectangular block of glass 6cm thick if a layer of water 4cm thick is on the top of glass.

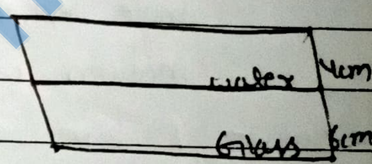
Given, refractive Index of Glass $= \frac{3}{2}$ $a\mu_g$

refractive Index of water $= 4/3$ $a\mu_w$

For glass (apparent shift)

$$d_2 = t_2\left(1 - \frac{1}{a\mu_g}\right)$$

$$= 6\left(1 - \frac{2}{3}\right) = 2$$



For water (apparent shift)

$$d_1 = t_1\left(1 - \frac{1}{a\mu_w}\right)$$

$$= 4\left(1 - 3/4\right)$$

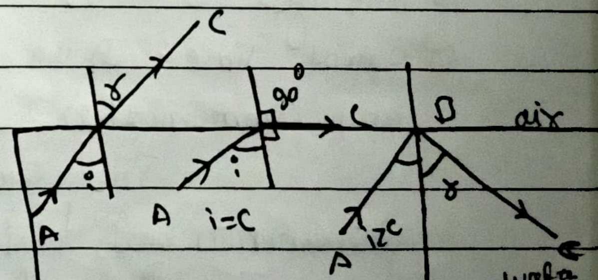
$$= 1$$

Then total shift d is given by

$d_1 + d_2$

$\therefore d = 3cm$

Total Internal reflection



When a ray of light passes from denser medium to rarer medium, it bends away from normal, thus an incident ray AD passes from water to air and bends away from normal in the direction of DC.

As we increase the angle of incidence there is a point where for a given angle of incident, the angle of refraction is exactly 90°. This condition is called critical condition. The critical angle is defined as angle of incidence for which the angle of refraction is 90° when a ray of ligh passes from denser to rarer

For a critical condition,

$i = C$ & $r = 90°$

then,

$$_w\mu_a = \frac{\sin i}{\sin r}$$

$$_a\mu_w = \frac{\sin r}{\sin i}$$

$$_a\mu_w = \frac{\sin 90}{\sin C} = {_a\mu_w} = \frac{1}{\sin}$$

If we increase the angle of incidence greater than critical angle then the refracted ray of light returns to same medium. which is known as total Internal reflection.

Condition for total Internal reflection

(i) The ray of light must be travelling from denser medium to rarer medium

(ii) The angle of incidence must be greater than critical angle

Some application of total internal reflection

(i) Mirage

(ii) Optical fibre :- It is a device which is used to transmit light and communication signal through total Internal reflection.

The working of optical fibre is based on the phenomenon of total Internal reflection

The optical fibre consist of two parts

(i) core (ii) cladding (iii) coating,

(i) Core:- The central cylindrical is core is made up of high quartz glass of refractive index of $\mu = 1$ and has diameter about 10 to 100 micrometer.

(ii) cladding:- The core is surrounded by a glass of refractive index μ_2 ($\mu_2 < \mu_1$) In typical optical fibre. the refractive index of core is greater than cladding