REFLECTION AND REFRACTION

REFRACTIVE INDEX

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(a) Refractive Index in terms of Speed of Light :

The refractive index of a medium may be defined in terms of the speed of light as follows :

The refractive index of a medium for a light of given wavelength may be defined at the ratio of the speed of light in vacuum to its speed in that medium.

Refractive index $= \frac{\text{Speed of light in vacuum}}{\text{Speed of light in medium}}$

or $\mu = \frac{c}{v}$

Refractive index of medium with respect to vacuum is also called absolute refractive index.

(b) Refractive Index in terms of Wavelength :

Since the frequency (υ) remain unchanged when light passed from on medium to another, therefore,

$$\mu = \frac{c}{v} = \frac{\lambda_{vac} \times \nu}{\lambda_{med} \times \nu} = \frac{\lambda_{vac}}{\lambda_{med}}$$

The refractive index of a medium may be defined as the ratio of wavelength of light in vacuum to its wavelength in that medium.

(c) Relative Refractive Index :

The relative refractive index of medium 2 with respect to medium 1 is defined at the ratio of speed of light

(v_1) in the medium 1 to the speed of light (v_2) in medium 2 and is denoted by ${}_1\mu_2$.

Thus, $\quad {}_1\mu_2 = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2} \quad = \frac{\mu_2}{\mu_1}$

As refractive index is the ratio of two similar physical quantities, so it has no **unit and dimension. Factors on which the refractive index of a medium depends are L**

(i) Nature of the medium.

(ii) Wavelength of the light used.

(iii) Temperature.

(iv) Nature of the surrounding medium

It may be note that refractive index is a characteristic of the pair of the media and also depends on the wavelength of light, but is independent of the angle of incidence.

Physical significance of refractive Index :

The refractive index of a medium gives the following two information's :

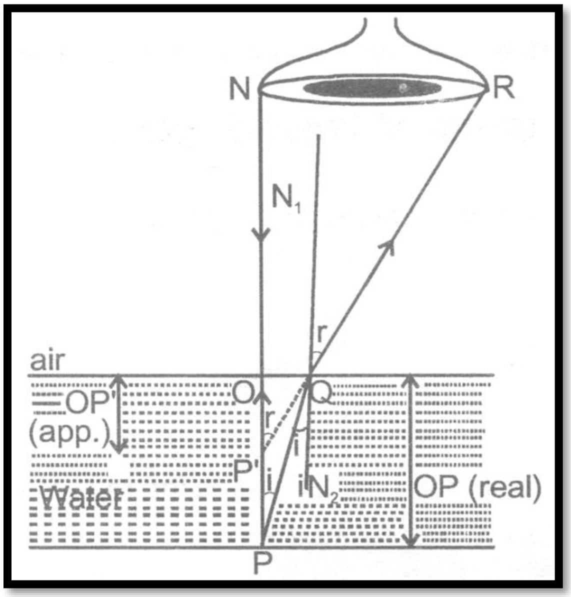
(i) The value of refractive index gives information about the direction of bending of refracted ray. It tells whether the ray will bend towards or away from the normal.

(ii) The refractive index of a medium is related to the speed of light. It is the ratio of the speed of light in vacuum to that in the given medium. For example, refractive index of glass is 3/2. This indicates that the ratio of the speed of light in glass to that in vacuum is 2 : 3 or the speed of light in glass is two-third of its speed in vacuum.

(d) Refractive Index in terms of apparent depth and read depth :

Whenever we observe the bottom of a swimming pool or a tank of clear water, we find that the bottom appears to be raises i.e. the apparent dept is less as compared to its real depth.

The extent to which the bottom appears to be raised depends upon the value of refractive index of the refracting medium.



In above fig. $\angle PQN_2 = \angle i$ & $\angle N_1OR = \angle r$

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

Or ${}_a\mu_w = \frac{\sin r}{\sin i}$ ………….(1)

As $\angle N_1QR = \angle OP'Q = \angle r$ (corresponding angles)

In $\Delta OP'Q$ $\sin r = \angle OP'Q = \frac{OQ}{P'Q}$ …………(2)

And $\angle i = \angle PQN_2 = \angle QPO$ (alt. Int. $(\angle s)$)

$\therefore$ In ΔQOP $\sin i = \sin\angle OPQ = \frac{OQ}{PQ}$ …………..(3)

So from (1) using (2) & (3)

${}_a\mu_w = \frac{OQ/P'Q}{OQ/PQ} = \frac{PQ}{P'Q}$ …………..(4)

nearly normal direction of viewing angle i is very small

PQ $\cong$ PO

& P;Q $\cong$ P'O

$\therefore$ from (4)

$${}_a\mu_w = \frac{PO}{P'O} \Rightarrow {}_a\mu_w = \frac{\text{Real depth}}{\text{Apparent depth}}$$

(e) Refraction and Speed of Light :

The refraction of light occurs because light has different speed in different media. Speed of light is maximum in vacuum or air. It is less in any other medium. Denser in the medium lesser is the speed of light. Refractive index of a medium depends not only on its nature and physical conditions, but also on the colour or wavelength of light. It is more for violet light and less for red light (VIBGYOR).

To find refractive index of two media w.r.t. each other when their refractive indices w.r.t. air are given. A ray of light AB refracts from different medium as shown in figure below.

(i) For refractive index at interface A'B'

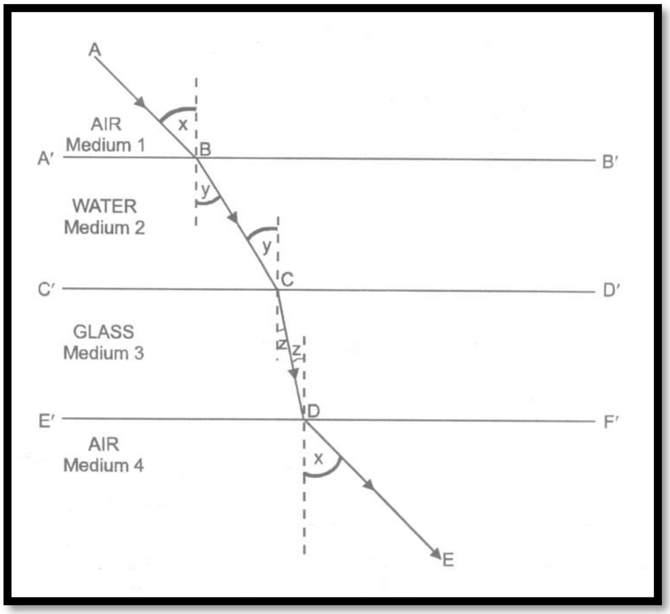
$${}_a\mu_w = \frac{\sin x}{\sin y} \qquad \text{..................(i)}$$

(ii) For refractive index at interface C'D'

$${}_a\mu_g = \frac{\sin y}{\sin z} \qquad \text{..................(ii)}$$

(iii) For refractive index at interface E'F'

$${}_g\mu_a = \frac{\sin z}{\sin x} \qquad \text{.................(iii)}$$



Multiply (1), (2) & (3)

$$_{a}\mu_{w} \times_{a} \mu_{g} \times_{q} \mu_{a} = 1$$

$$_{q}\mu_{g} = \frac{1}{_{a}\mu_{w} \times_{g} \mu_{a}}$$

$$_{w}\mu_{g} = \frac{_{a}\mu_{g}}{_{a}\mu_{w}} \qquad \text{....................(iv)} \qquad \left(\text{as} \frac{1}{_{g}\mu_{a}} =_{a} \mu_{g}\right)$$

and on reciprocal

$$_{g}\mu_{w} = \frac{_{a}\mu_{w}}{_{a}\mu_{g}} \qquad \text{....................(v)}$$

$\therefore$ In general we can write as

$$_{2}\mu_{3} = \frac{_{1}\mu_{3}}{_{1}\mu_{2}}$$

$$_{3}\mu_{2} = \frac{_{1}\mu_{2}}{_{1}\mu_{3}}$$

Illustration :

Calculate the speed and wavelength of light (i) in glass & (ii) in air, when light waves of frequency 6×10^{14}

Hz. travel from air to glass of $\mu = 1.5$.

Sol. Here $\nu = 6 \times 10^{14}$ Hz. $\mu = 1.5$

(i) In glass speed of light $V_g = \frac{V_a}{\mu} = \frac{3 \times 10^8}{1.5} = 2 \times 10^8 \text{ m/s}$

Wavelength of light $\lambda_9 = \frac{V_g}{\nu} = \frac{2 \times 10^8}{6 \times 10^{14}} = 3.3 \times 10^{-7} \text{m.}$

(ii) In air speed of light $V_a = 3 \times 10^8 \text{ m/s}$

Wavelength of light $\lambda_a = \frac{V_a}{\nu} = \frac{3 \times 10^8}{6 \times 10^{14}} = 5 \times 10^{-7} \text{m.}$

REFRACTIN THROUGH GLASS SLAB :

Refraction through a rectangular glass slab :

Consider a rectangular glass slab, as shown in figure. A ray AE is incident on the face PQ at an angle of incidence I. on entering the glass slab, it bends towards normal and travels along EF at an angle of refraction **r.** The refracted ray EF is incident on face SR at an angle of incidence **r'**. The emergent ray FD bends away from the normal at an angle of refraction **e.**

Thus the emergent ray FD is parallel to the incident ray AR, but it has been laterally displaced with respect to the incident ray. There is shift in the path of light on emerging from a refracting medium with parallel faces.

Lateral shift :

Lateral shift is the perpendicular distance between the incident and emergent rays when light is incident obliquely on a refracting slab with parallel faces.

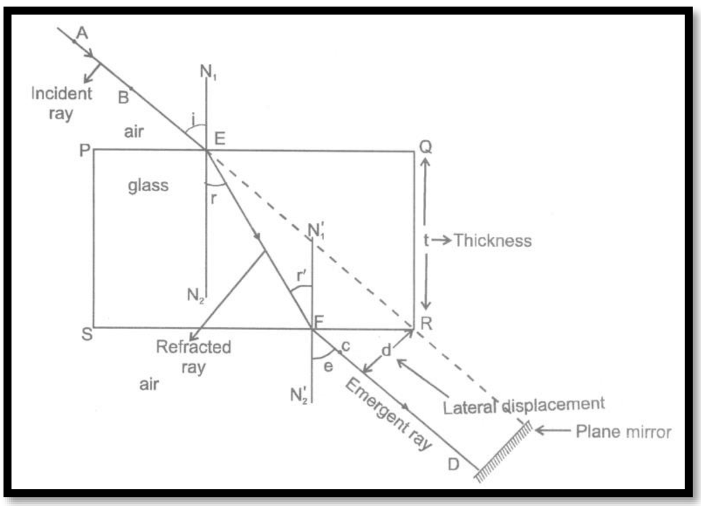
Factors on which lateral shift depends are :

(i) Lateral shift is directly proportional to the thickness of glass slab.

(ii) Lateral shift is directly proportional to the incident angle.

(iii) Lateral shift is directly proportional to the refractive index of glass slab.

(iv) Lateral shift is inversely proportional to the wavelength of incident light.



Filgure : :Lateral shifting of light iln glass slab

If a plane mirror is placed in the path of emergent ray FD then the path of the emergent ray along FD is reversed back, it follows the same path along which it was incident i.e. the incidence ray becomes the emergent ray & emergent ray becomes the incident ray. It is known as principle of reversibility of light.

Case - I : For light going from air to glass of point E.

$\angle i$ = angle of incident, $\angle r$ angle of refraction.

$${}_a\mu_g = \frac{\sin i}{\sin r} \quad \text{.................(1)} \quad ({}_a\mu_g = \text{absolute refractive index of glass})$$

Case - II : For light going from glass to air at point F.

$$\Rightarrow \quad {}_g\mu_a = \frac{\sin g}{\sin e} \qquad \text{where} \begin{Bmatrix} \angle r = \text{angle incidence} \\ \angle e = \text{angle of refraction} \end{Bmatrix} \therefore \angle r = \angle$$

$$\Rightarrow {}_g\mu_a = \frac{\sin r}{\sin i} \quad (\text{as } \angle e = \angle i)$$

$$\therefore \frac{1}{{}_g\mu_a} = \frac{\sin i}{\sin r} \quad \text{...............(2)}$$

$\therefore$ From (1) & (2)

$${}_a\mu_g = \frac{1}{{}_g\mu_a} \qquad \Rightarrow \qquad \lfloor {}_a\mu_g \times {}_g\mu_a = 1 \rfloor$$