Refraction of light

Change in the path of the light as it moves from one optical medium to another optical medium having different refractive index.

* The phenomenon is the change in the path of light in going from one medium to another is called refraction of light.

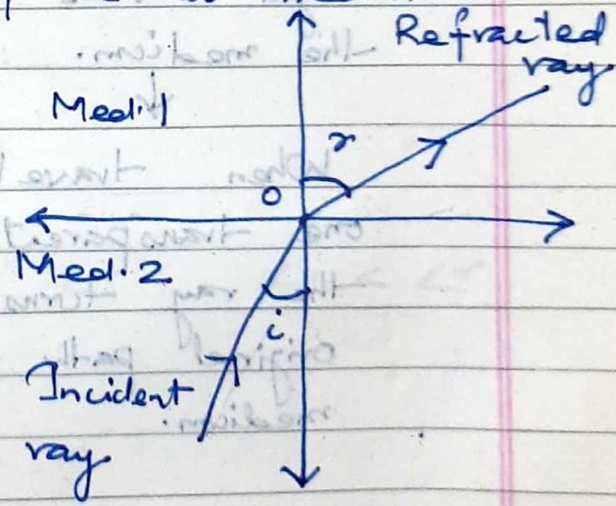
OR

Refraction: It denotes bending of light from its original path on entering another medium.

* The refraction occurs occurs right at the boundary of the two media.

∠i = Angle of incidence

∠r = Angle of refraction



1) Bending of pencil

2) Apparent height of water tank (coin)

observations:

i) When a thick glass slab is placed over a printed page, the letters appear raised when viewed through the glass slab.

ii) A coin in a glass tumbler filled with water appears to be raised, when seen from above the water.

iii) A lemon kept in water in a glass viewed from sides, appears to be bigger than its actual size.

Note: The extent of the effect is different for different pairs of media.

Air – Water
Air – Kerosene
Air – turpentine oil

The aparent rise of a coin in a glass tumbler changes when it is filled with a liquid other than water.

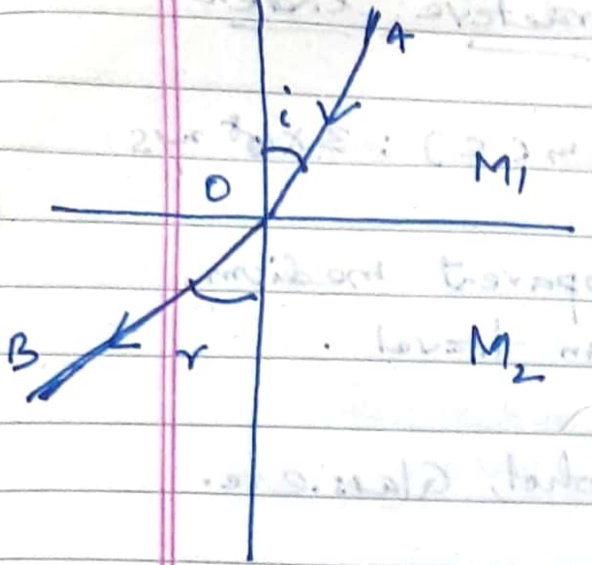
Light travels in straight line in both the medium.

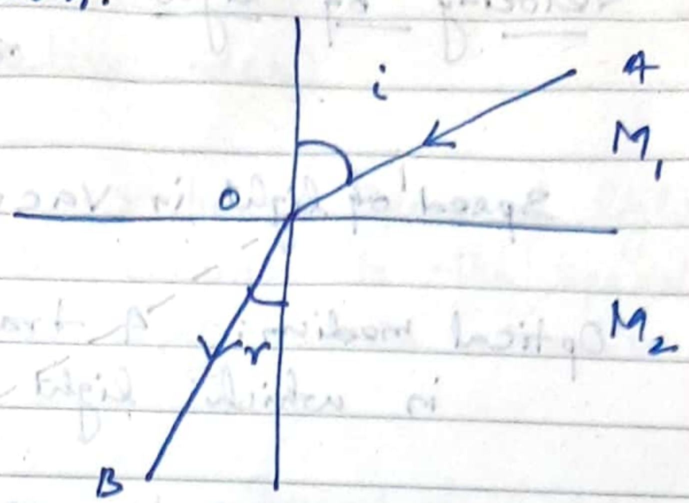
↓

When travelling obliquely from one transparent medium to another the ray turns or bends from its original path on entering into another medium.

Defn

[The phenomenon of change in path of light in going from one medium to another is called refraction of light.] Thus refraction of light is the phenomenon of bending of light from its original path on entering another medium.





OA:

OB:

∠i:

∠r:

Plane of incidence:

Plane of refraction:

$\angle i = \angle r$ $\angle i > \angle r$ $\angle i < \angle r$

Velocity of light : Concept of refractive index

Speed of light in vacuum (c) : 3×10^8 m/s

Optical medium : A transparent medium in which light can travel.

Ex. Air, Water, Alcohol, Glass etc.

Different optical media have different optical densities.
↓
Speed of light in different media is different.

Medium (Speed of light)

More → Rarer

less → Denser

Rarer, Denser → Relative terms.
↓
Compared with another medium.

Air : 3×10^8 m/s

Water : 2.25×10^8 m/s

Glass : 2×10^8 m/s

Medium
(Refractive index)

Refractive index: ratio of speed of light in vacuum to the speed of light in the medium.

$$\text{Refractive index } (n) = \frac{\text{Speed of light in Vacuum}}{\text{Speed of light in medium.}}$$

$$= c/v$$

$$n_{glass} = \frac{\text{Speed of light in air}}{\text{Speed of light in glass}}$$

$$= \frac{3 \times 10^8}{2 \times 10^8} = 1.5$$

$$n_{water} = \frac{c}{v}$$

$$= \frac{3 \times 10^8}{2.25 \times 10^8} = \frac{4}{3}$$

$$= 1.33$$

$$n_{free\ space} = \frac{c}{v} = \frac{c}{c} = 1.$$

Unit: Ratio of similar quantities (no units)

$d = m/V \quad kg\ m^{-3}$

Medium
(n)

High — Denser

low — Rarer.

$\uparrow n = c/v \downarrow$

n = high, V = less

n = less, V = high.

Denser medium (n = high) : Speed of light : slow

Rarer medium (n = low) : Speed of light : Fast

Note:

Refractive index is a characteristic property of the medium, whose value depends only on nature of material of the medium and the colour or wavelength of light.

Relative refractive index:

$^1n_2 = \frac{n_2}{n_1}$ $\quad$ $^2n_1 = n_1/n_2$

NCERT $n_{12} = \frac{n_2}{n_1}$ $\quad$ $n_{21} = n_1/n_2$

When light passes from med. 1 (2) to med. 2 (1) the refractive index of 2 (1) with respect to med. 1 (2) is written as $^1n_2$ ($^2n_1$)

or

n_{12} (n_{21})

$$^1n_2 = \frac{n_2}{n_1}$$

V_1: Speed of light in med. 1

$$= \frac{c/V_2}{c/V_1}$$

V_2: Speed of light in med. 2

$$\frac{n_2}{n_1} = \frac{V_1}{V_2}$$

$$= \frac{\text{Speed of light in med. 1}}{\text{Speed of light in med. 2}}$$

$$n_{12} \times n_{21} = \frac{n_2}{n_1} \times \frac{n_1}{n_2}$$

$$= 1$$

$$n_{12} = 1/n_{21}$$

or

$$n_{21} = 1/n_{12}$$

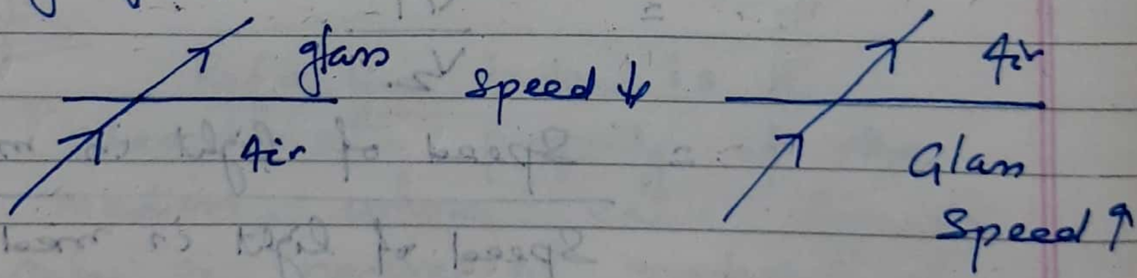
$n_{wg} = x$ $\quad$ $n_{gw} = 1/x$

The absolute refractive index of a medium is simply called its refractive index.

Optical density of a medium determines the ability of the medium to refract light. It is not the same as mass density of the medium.

CAUSE:

Change in speed of light in going from one medium to other.



Angle of bending of a ray depend upon difference in speeds of light in the two media.

3×10^8 — 2×10^8

Air — glass — bend more

Air — water — bend less

2.25×10^8

LAWS OF REFRACTION

1. Whenever light goes from one medium to another, the freq. of light does not change. However, the velocity of light and the wavelength of light change.

2. The incident ray, refracted ray and normal to the interface of two media at the point of incidence, all lie in the same plane.

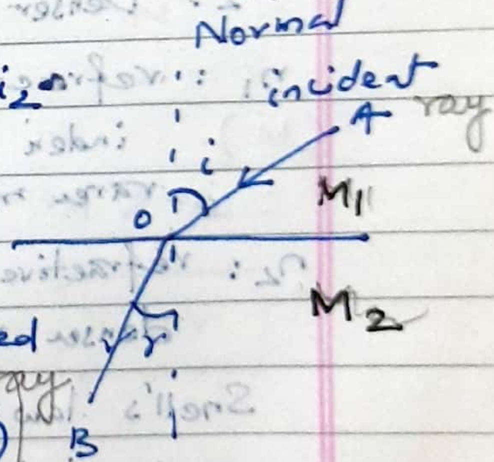
3. The product of refractive index and sine of angle of incidence at a point in a medium is const.

$$n \sin i = \text{const.}$$

$$n_1 \sin i_1 = n_2 \sin i_2$$

$i_1 = i \quad i_2 = r$

$$n_1 \sin i = n_2 \sin r$$



$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = {}^1n_2 \ (n_{12})$$

Snell's law:

Note:

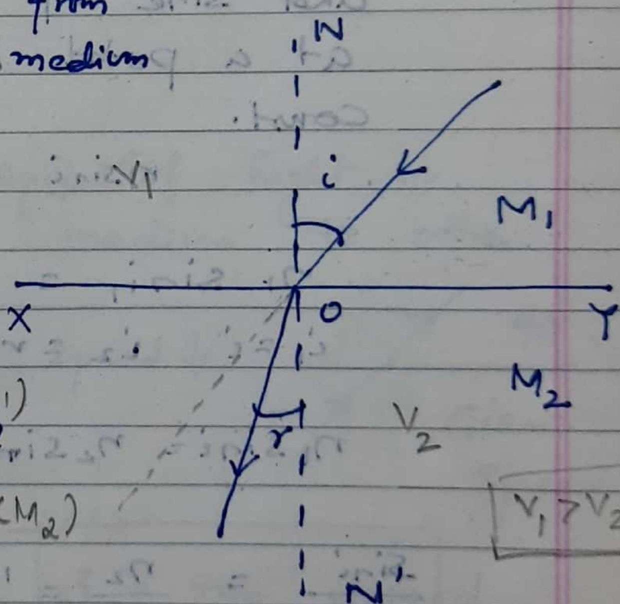
* Refractive index represents the extent of the change in direction that takes place in a given pair of media.

* n : relative speed of propagation of light in different media.

The Direction of Bending of light

Case 1:

Ray of light going from rarer to denser medium



$V_1 > V_2$

M_1 : Rarer medium

M_2 : Denser medium

n_1 : refractive index of rarer medium (M_1)

n_2 : refractive index of denser medium. (M_2)

Snell's law:

$(M_1)\ n_1 \sin i = n_2 \sin r\ (M_2)$

$$\boxed{\frac{\sin i}{\sin r} = \frac{n_2}{n_1}}$$

$n_2 > n_1$

$$\frac{\sin i}{\sin r} > 1$$

	$0°$	$30°$	$45°$	$60°$	$90°$
Sin	0	$\frac{1}{2}$	$1/\sqrt{2}$	$\sqrt{3}/2$	1
		0.5	0.707	0.866	1

$\sin i > \sin r$

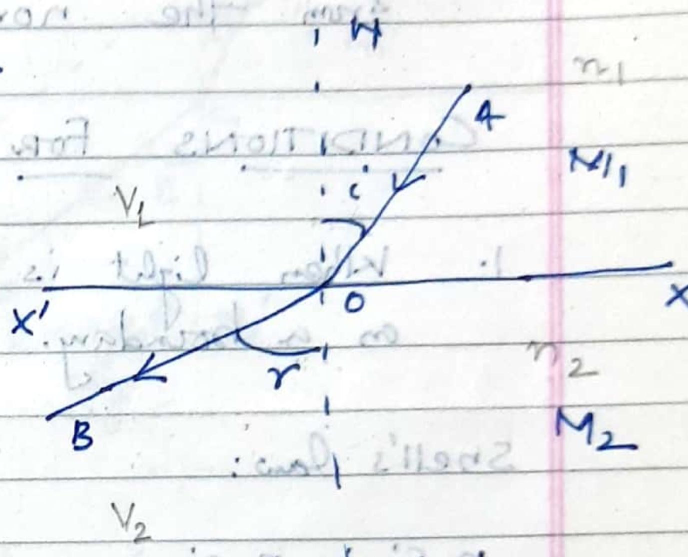
$\boxed{i > r}$

Note:

When light travels from a rarer medium to a denser medium, it bends towards normal at the interface of two media.

Case 2:

Ray of light going from denser to a rarer medium.



M_1 : Denser medium

M_2 : Rarer medium

n_1 : refractive index of denser medium

n_2 : refractive index of rarer medium

Snell's law:

$$n_1 \sin i = n_2 \sin r$$

$$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} < 1 \qquad n_1 > n_2$$

$V_2 > V_1$

$$\sin i < \sin r$$

$$i < r$$

Note:

When light travels from a denser medium to a rarer medium, it bends away from the normal at the interface of two media.

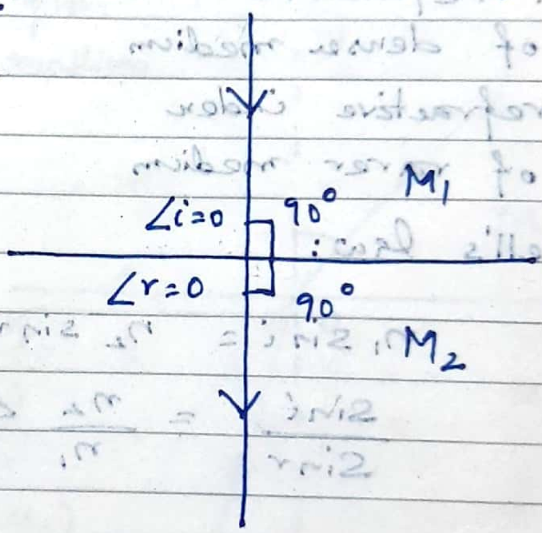
Note:

A ray of light travelling from a rarer to a denser medium slows down and bends towards the normal.

When the rays of light travel from denser medium to a rarer medium, it speeds up and bends away from the normal.

CONDITIONS FOR NO ~~REACTION~~ REFRACTION

1. When light is incident normally on a boundary.



Snell's law:

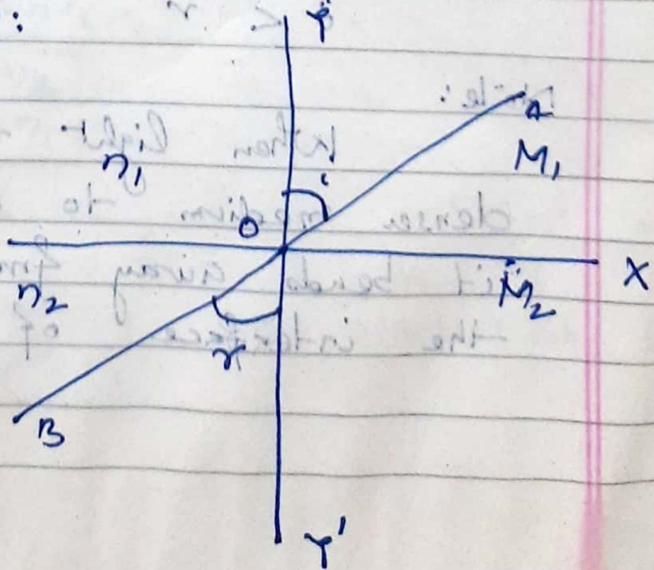
$n_1 \sin i = n_2 \sin r$

$\sin r = \frac{n_1}{n_2} \sin i$

$\sin r = 0$

$r = 0$

2. When the refractive indices of two media are equal:



$n_1 \sin i = n_2 \sin r$

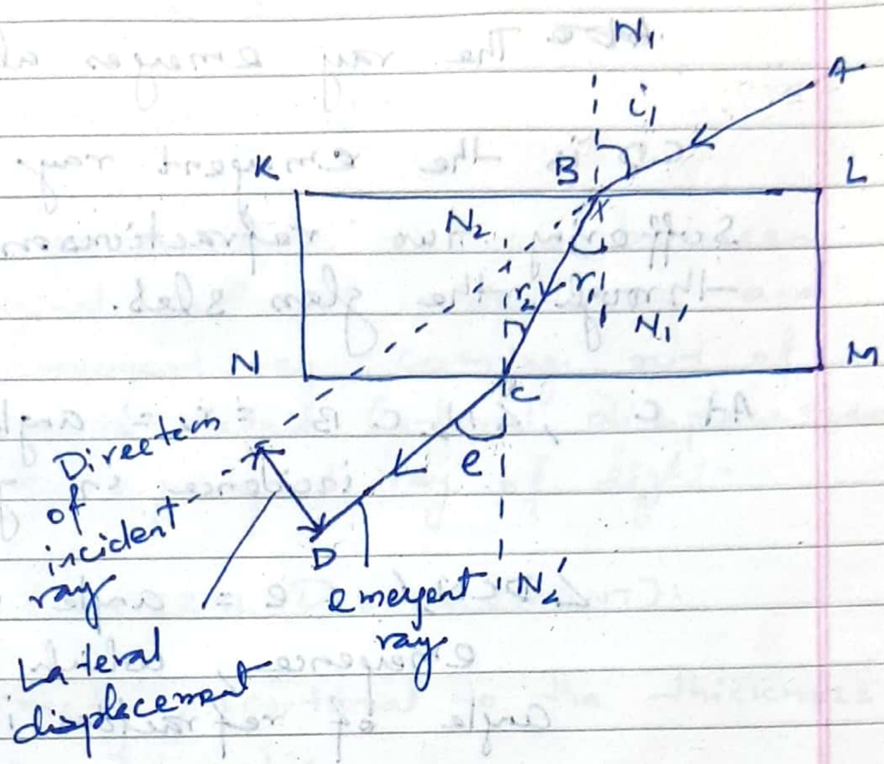
$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

$\frac{\sin i}{\sin r} = 1 \quad (\because n_1 = n_2)$

$\sin i = \sin r$

$\boxed{i = r}$

TWO REFRACTIONS THROUGH A GLASS RECTANGULAR SLAB



KLMN is a rectangular glass slab.

A ray of light travelling in air along AB falls on KL at angle of incidence $i_1 = \angle N_1BA$.

The ray AB will bend towards the (N_1BN_1') normal because it is travelling from rarer to denser medium.

The refracted ray will go along BC at angle of ~~incidence~~ refraction

$r_1 = \angle CBN_1'$

from Snells law:

$$n_a \sin i_1 = n_g \sin r_1 \quad \text{—— (1)}$$

where, n_a, n_g represents refractive indices

SO_4^{2-} ~~$3H_2SO_4 + 2Al \rightarrow Al_2(SO_4)_3 + 3H_2$~~

of air, glass respectively.

At point C, light ray will get refracted again.

~~ABD~~ The ray emerges along CD.

CD is the emergent ray after suffering two refractions on passing through the glass slab.

At C, $\angle N_2CB = r_2$ = angle of incidence in glass.

$\angle DCN_2' = e$ = angle of emergence, which is angle of refraction in air.

Applying Snell's law at C

$$n_g \sin r_2 = n_a \sin e \quad \text{—— (2)}$$

N_1N_1', N_2N_2' are normals to the plane of the glass slab.

$\therefore$ N_1N_1', N_2N_2' are parallel lines.

Ray BC is the transversal.

$\therefore$ $\angle r_1 = \angle r_2$

$$\sin r_1 = \sin r_2 \quad \text{—— (3)}$$

$$n_g \sin r_1 = n_g \sin r_2 \quad \text{---- (4)}$$

$\therefore$ From 1, 2 we get

$$n_a \sin i_1 = n_a \sin e$$

$$\sin i_1 = \sin e$$

$$\boxed{i_1 = e}$$

Scanned with CamScanner

Note:

Light emerges from rectangular glass slab in a direction parallel to that in which it entered the glass slab.

Lateral displacement

The perpendicular distance between the original path of incident ray and the emergent ray coming out of a glass is called lateral displacement of the emergent ray of light.

FACTORS (LATERAL DISPLACEMENT):

a) directly proportional to the thickness of glass slab.

b) directly proportional to the incident angle.

c) directly proportional to the refractive index of glass slab.

d) inversely proportional to the wavelength of incident light.

Q4 Aim: To verify the laws of refraction and determine the refractive index of the glass.

Ans. Materials Req.: Rectangular glass slab, White sheet of drawing paper, Drawing board, Drawing pins and all purpose pins.