Refraction

Sunday, April 19, 2020 8:08 AM

Em waves → Radio, Gamma, Ultraviolet, Visible, Infrared, X-Ray, γ-Ray

Refraction.

Bending of light when it travels from one medium to another medium.

Refractive Index (n)

It is the ratio of speed of light in vaccum to the speed of light in a given medium.

(RI doesn't have any unit)

i.e $n = \frac{c}{v}$

c : speed of light in vaccum (or) in air

v : speed of light in a given.

$c : 3\times10^8\,m/s = 3\times10^5\,km/s$

NOTE : * speed of light in any medium other than vaccum & air is always less than $3\times10^8\,m/s$

* When light travels from one medium to another medium,
  - → the frequency remains constant
  - → And wave length changes & therefor speed changes

speed $v = f\lambda$ (or) $v = \nu\lambda$

f (or) ν : frequency

λ : wavelength.

Example problem

① the speed of light in some medium is $1.5\times10^8\,m/s$. what is the RI of that medium.

solution

WKT

$n = \frac{c}{v} = \frac{3\times10^8}{1.5\times10^8} = 2$

n (or) μ

② RI of a glass medium is 1.5, what is the speed of light in it?

solution

WKT $n = \frac{c}{v}$

$1.5 = \frac{3\times10^8}{v}$

$\therefore v = \frac{3\times10^8}{1.5} = 2\times10^8\,m/s$

(8) speed of light in medium A is 2.25×10^8 m/s & in medium B the speed is 2×10^8 m/s. find ratio of RI of medium A to medium B.

Solution

WKT

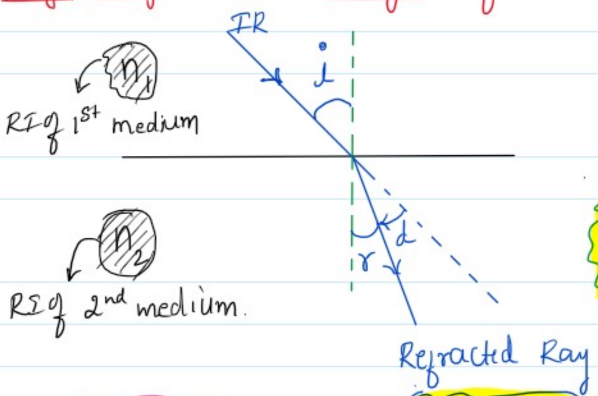
$$n = \frac{c}{v}$$

$$\therefore n_A = c/v_A \quad \& \quad n_B = c/v_B$$

$$\therefore \frac{n_A}{n_B} = \frac{c/v_A}{c/v_B} = \frac{c}{c} \times \frac{v_B}{v_A} = \frac{2 \times 10^8}{2.25 \times 10^8} = \frac{1}{1.125}$$

$$= 1 : 1.125$$

Ray diagram indicating Refraction

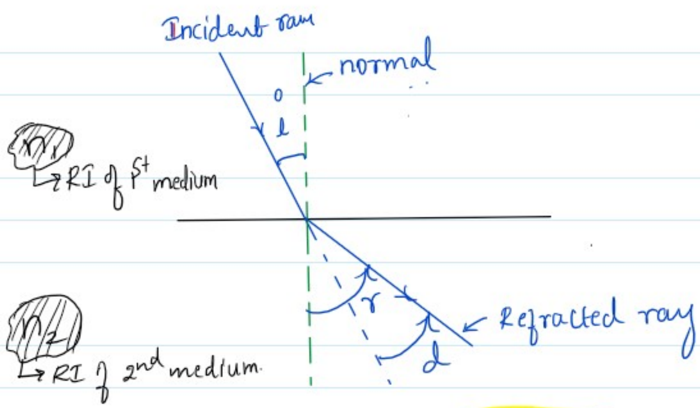


i: angle of incidence
r: angle of refraction
d: angle of deviation.

Whenever light travels from Rarer medium to denser medium it will always bends towards the normal

$\therefore n_2 > n_1$ $\therefore d = i - r$

i.e n_1 is rarer medium & n_2 is denser medium.



Whenever light travels from denser medium to rarer medium it always bends away from normal.

$\therefore n_1 > n_2$

$d = r - i$

laws of Refraction

* IR, RR & the normal drawn at the point of incidence lie on the same

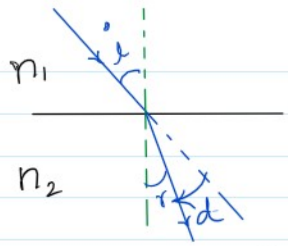
* IR, RR & the normal drawn at the point of incidence lie on the same plane

* Snell's law

It states that "the ratio of sine of angle of incidence to the sine of angle of refraction is constant for a given pair of medium & for a given wavelength of light".

i.e $\frac{\sin i}{\sin r} = \text{const}$

The Const = $\frac{\text{RI of 2nd medium}}{\text{RI of 1st medium}}$



$\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{c/v_2}{c/v_1} = \frac{v_1}{v_2}$

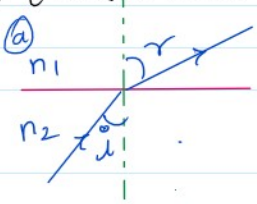
$\therefore \frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\not{f}\lambda_1}{\not{f}\lambda_2}$

finally $\frac{\sin i}{\sin r} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

Sample problem.

① Comment about the medium from which the ray is travelling

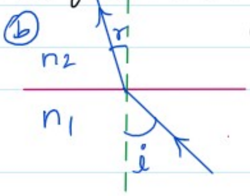
(a)



The ray is travelling from denser to rarer

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

(b)



The ray is travelling from rarer to denser.

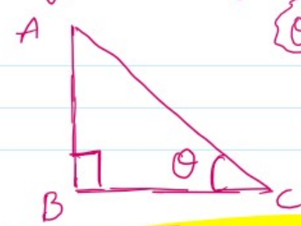
$\frac{\sin i}{\sin r} = \frac{n_2}{n_1}$

②

what is the RI of glass?

Trigonometry

θ: theta



$\sin\theta = \frac{opp}{hyp} = \frac{AB}{AC}$

$\cos\theta = \frac{adj}{hyp} = \frac{BC}{AC}$

$\tan\theta = \frac{opp}{adj} = \frac{AB}{BC}$

$\cot\theta = \frac{adj}{opp} = \frac{BC}{AB} = \frac{1}{\tan\theta}$

$\sec\theta = \frac{hyp}{adj} = \frac{AC}{BC} = \frac{1}{\cos\theta}$

$\text{cosec}\,\theta = \frac{hyp}{opp} = \frac{AC}{AB} = \frac{1}{\sin\theta}$

NOTE

* $\tan\theta = \frac{\sin\theta}{\cos\theta} = \frac{opp/hyp}{adj/hyp} = \frac{opp}{adj}$

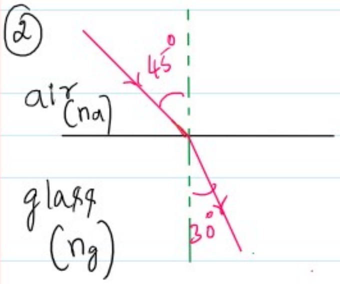
* $\sin^2\theta + \cos^2\theta = 1$

Proof

$= \left(\frac{opp}{hyp}\right)^2 + \left(\frac{adj}{hyp}\right)^2$

$= \frac{opp^2 + adj^2}{hyp^2} = \frac{hyp^2}{hyp^2} = 1$ (By pythagorous theorem)

(2)



What is the RI of glass?

NOTE

* RI of air = 1

$n_{air} = \frac{c_{vac}}{V_{air}} = 1$

Solution

WKT by Snell's law

$$\frac{\sin i}{\sin r} = \frac{n_g}{n_a}$$

$$\frac{\sin 45}{\sin 30} = \frac{n_g}{1}$$

$$\therefore n_g = \frac{1/\sqrt{2}}{1/2}$$

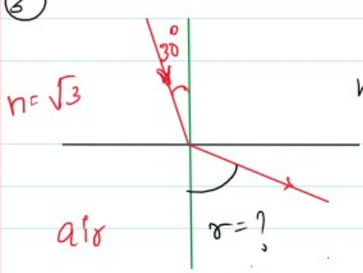
$$= 2/\sqrt{2} = \frac{\sqrt{2}\times\sqrt{2}}{\sqrt{2}}$$

$\because 2 = \sqrt{2}\times\sqrt{2} = (\sqrt{2})^2 = 2$

$$n_g = \sqrt{2}$$

$$n_g = 1.414$$

(3)



A ray travels from a medium of RI $\sqrt{3}$ to air medium. Find angle of refraction.

Solution

$$\frac{\sin 30}{\sin r} = \frac{1}{\sqrt{3}}$$

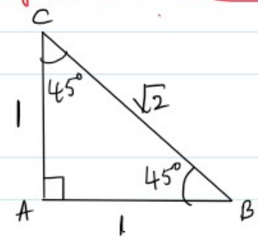
$$\sin r = \sqrt{3} \times \sin 30$$

$$\sin r = \sqrt{3} \times 1/2$$

$$= \frac{opp^2 + adj^2}{hyp^2} = \frac{hyp^2}{hyp^2} = 1$$

$$\therefore \sin^2\theta + \cos^2\theta = 1$$

Trigonometric ratio for Standard angle

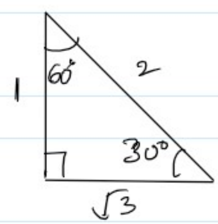


$AC^2 + AB^2 = BC^2$

$1^2 + 1^2 = BC^2$

$\therefore BC = \sqrt{2}$

* $\sin 45° = \frac{opp}{hyp} = \frac{1}{\sqrt{2}}$
* $\cos 45° = \frac{adj}{hyp} = \frac{1}{\sqrt{2}}$
* $\tan 45° = \frac{opp}{adj} = 1$
* $\cot 45° = \frac{1}{\tan 45} = 1$
* $\sec 45° = \frac{1}{\cos 45} = \sqrt{2}$
* $\mathrm{cosec}\, 45° = \frac{1}{\sin 45} = \sqrt{2}$



* $\sin 30 = \frac{1}{2}$
* $\cos 30 = \frac{\sqrt{3}}{2}$
* $\tan 30 = 1/\sqrt{3}$
* $\cot 30 = \sqrt{3}$
* $\sec 30 = 2/\sqrt{3}$
* $\mathrm{cosec}\, 30 = 2$

* $\sin 60 = \sqrt{3}/2$
* $\cos 60 = 1/2$
* $\tan 60 = \sqrt{3}$
* $\cot 60 = 1/\sqrt{3}$
* $\sec 60 = 2$

$\sin r = \sqrt{3} \times 1/2$

$\sin r = \sqrt{3}/2$

$\Rightarrow r = 60°$

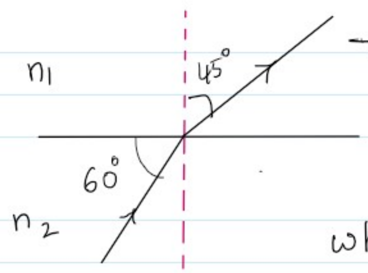
$* \sec 60 = 2$

$* \operatorname{cosec} 60 = 2/\sqrt{3}$

TO summarise.

	0°	30°	45°	60°
sin	0	1/2	$1/\sqrt{2}$	$\sqrt{3}/2$
cos	1	$\sqrt{3}/2$	$1/\sqrt{2}$	1/2
tan	0	$1/\sqrt{3}$	1	$\sqrt{3}$

Home work



→ it is found that the speed of light in n_2 is 2×10^8 m/s.

what is the speed of light in n_1 ?

→ Also find angle of deviation.

$\because \frac{n_1}{n_2} = \frac{c/v_1}{c/v_2} = \frac{v_2}{v_1}$

solution

By snell's law $\frac{\sin i}{\sin r} = \frac{n_1}{n_2} = \frac{v_2}{v_1}$

$\therefore \frac{\sin i}{\sin r} = \frac{v_2}{v_1}$

$\frac{\sin(30)}{\sin(45)} = \frac{2 \times 10^8}{v_1}$

$\therefore v_1 = 2 \times 10^8 \times \frac{\sin 45}{\sin 30}$

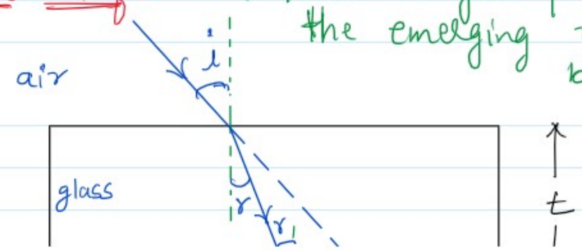
$= 2 \times 10^8 \times \frac{1/\sqrt{2}}{1/2}$

$= 2 \times 10^8 \times 2/\sqrt{2}$ $\quad \because \frac{2}{\sqrt{2}} = \frac{\sqrt{2} \times \sqrt{2}}{\sqrt{2}}$

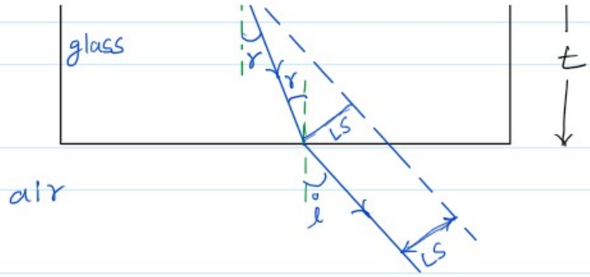
$= \sqrt{2} \times 2 \times 10^8$

$= 1.41 \times 2 \times 10^8 = 2.82 \times 10^8$ m/s

lateral shift : when a light passes through a parallel sided glass slab, the emerging ray & the incident ray are parallel but the emerging ray shifts laterally by a distance called lateral shift (LS)



NOTE : The emerging ray will be parallel



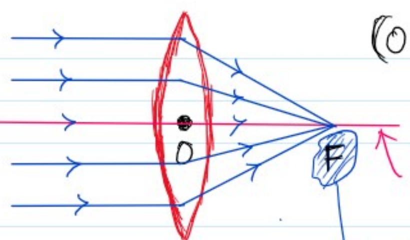
NOTE : The emerging ray will be parallel to incident ray only if

* the glass slab is parallel sided
* RI of Incident ray medium = RI of Emerging ray medium.

Refraction on Lens → optical medium bound by 2 surface of which atleast one is spherical.

There are 2 types ① convex lens.
② concave lens

Convex lens : In this lens the thickness at the middle is greater than thickness at the end.



(O) optical centre : it is the centre of lens about which the incident ray goes undeviated

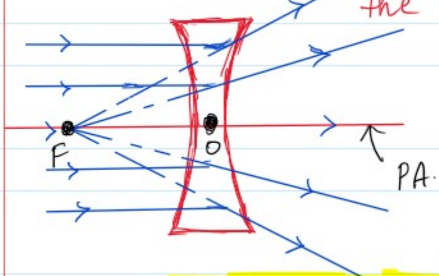
principal axis : Horizontal line passing through optic centre

principal focus : it is a point on the PA about which the IR parallel to PA after refraction appears to be converging (or) diverging from is called PF.

NOTE Generally convex lens is also called as converging lens

→ uses : To correct long sightedness, used in microscope & telescope

Concave lens : In this lens thickness at the middle is less than thickness at the end.

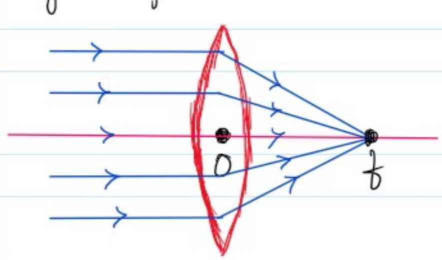


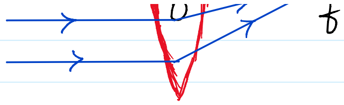
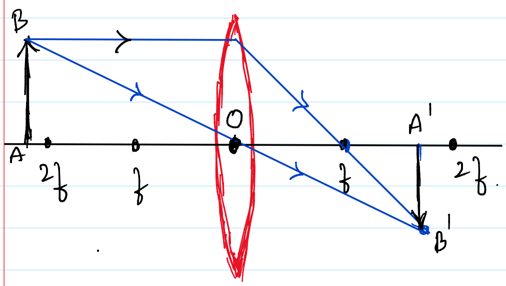
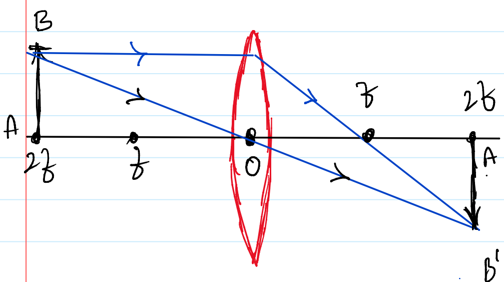
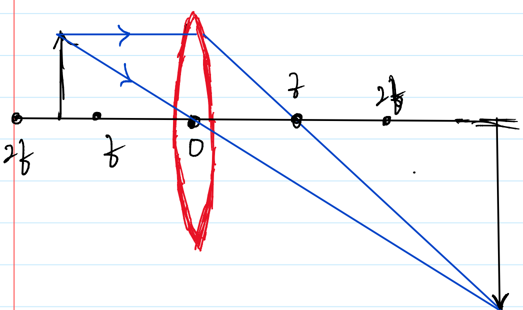
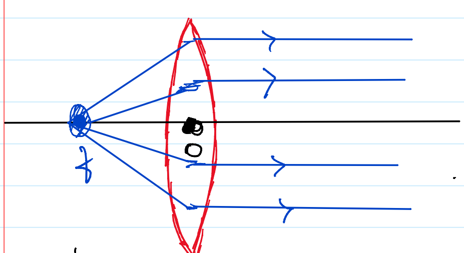
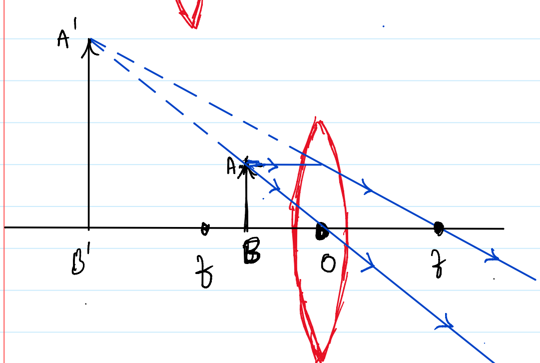
NOTE

Generally concave lens is also called as diverging lens.

→ uses : To correct shortsightedness

Ray diagram for convex lens

Ray diagram	object dist	image dist	Nature of image.
	$u = \infty$	$v = f$	Real inverted & point size.

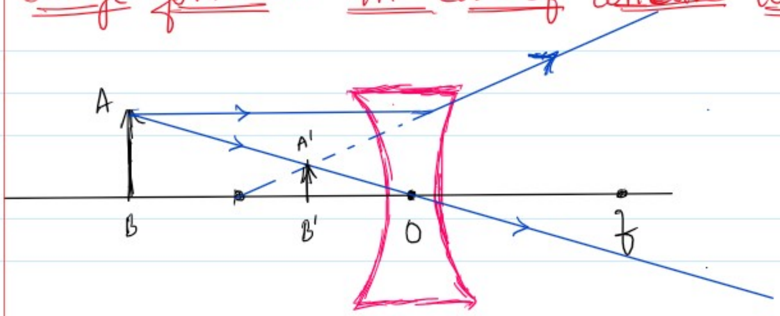
			
	$u > 2f$	$f < v < 2f$	Real inverted diminished.
	$u = 2f$	$v = 2f$	Real inverted & same size.
	$2f > u > f$	$v > 2f$	Real inverted magnified.
	$u = f$	$v = \infty$	highly magnified.
	$u < f$	on the same side of object	Virtual erect & magnified.

NOTE : At 2 position of an object in front of convex lens we get magnified image,

① $2f > u > f$: Image is Real

② $u < f$: Image is virtual.

Image formation in case of concave lens



NOTE : No matter where the object is infront of concave lens, the image is always formed b/w focus & optic centre & nature is always

→ virtual
→ Erect
→ diminished.

Lens formula

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

Magnification formula

$$m = \frac{h_i}{h_o} = \frac{v}{u}$$

Power of lens

$$P = \frac{1}{f}$$

its unit is m^{-1} (or) diopter (D)