REFRACTION OF LIGHT

Refraction: -

While travelling obliquely from one medium to another, the direction of propagation of light in the second medium changes. This phenomenon is known as refraction of light.

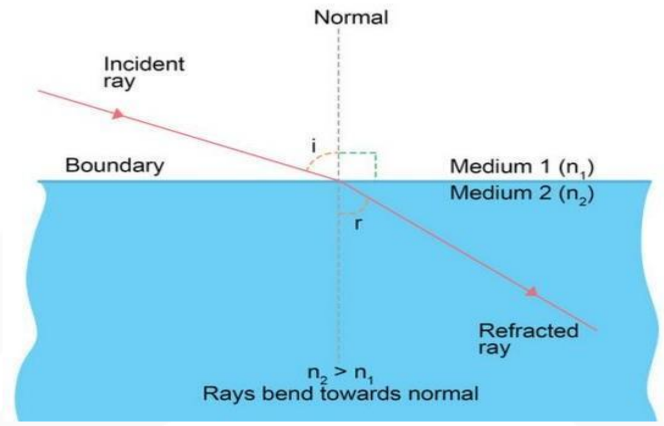
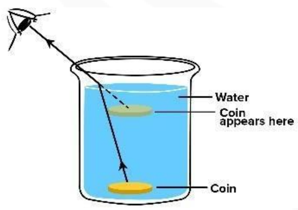


Fig. 1

Examples of refraction of light: -

i) The bottom of a tank or a pond containing water appears to be raised or a coin in a tumbler



appears raised. Fig.2

ii) A thick glass slab is placed over some printed matter; the letters appear raised when viewed through the glass slab.

iii) A pencil partly immersed in water in a glass tumbler; It appears to be displaced at the

interface of air and water. Fig. 3

Refraction through a Rectangular Glass Slab: -

When the light is incident on a rectangular glass slab, it emerges out parallel to the incident ray and is laterally displaced. It moves from rarer to a denser medium and then again to a rarer medium.

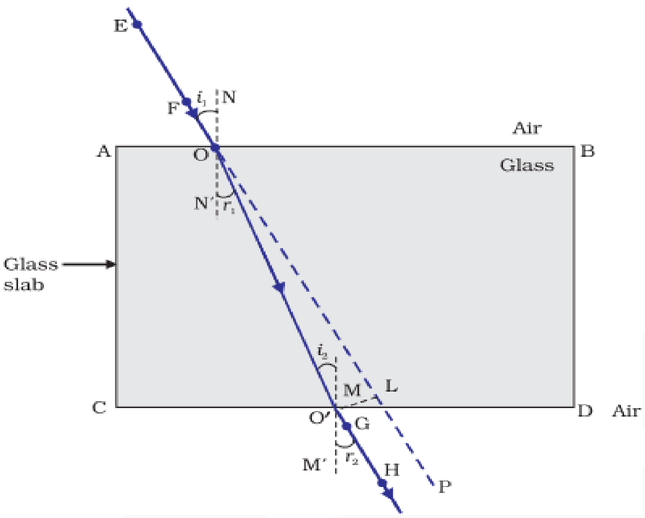


Fig. 4

Laws of Refraction: -

The following are the laws of refraction of light.

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

(ii) The ratio of sine of angle of incidence to the sine of angle of refraction is a constant, for the light of a given color and for the given pair of media.

This law is also known as Snell's law of refraction.

If i is the angle of incidence and r is the angle of refraction, then,

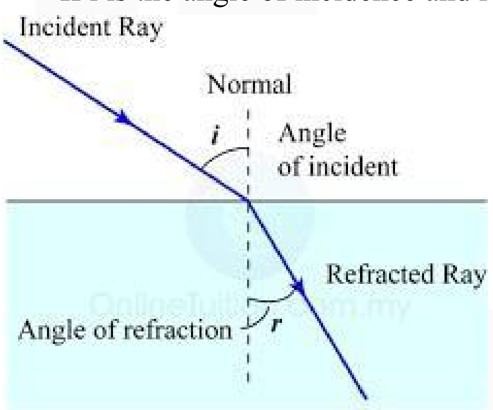


Fig. 5

$$\text{Sin } i / \text{Sin } r = \mu$$

Where μ is called Refractive Index and its constant for a medium.

REFRACTIVE INDEX

#Relative Refractive Index: -

- The extent of the change in direction of a ray of light travelling obliquely in a given pair of media is expressed in terms of the refractive index.

It can be expressed by

Sin i / Sin r = n_{21}

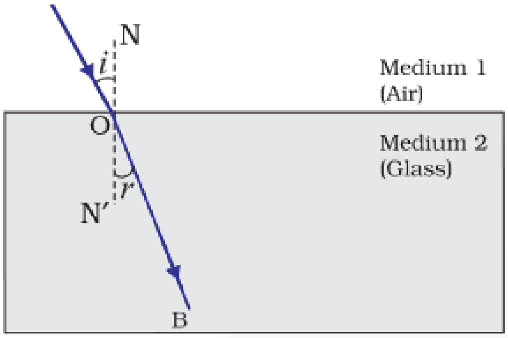


Fig. 6

- The value of the refractive index for a given pair of media also depends upon the speed of light in the two media, as given below.

i) The refractive index of medium 2 with respect to medium 1 is given by the ratio

$$n_{21} = \frac{\text{Speed of light in medium 1}}{\text{Speed of light in medium 2}} = \frac{v_1}{v_2}$$

ii) The refractive index of medium1 with respect to medium 2 is given by

$$n_{12} = \frac{\text{Speed of light in medium 2}}{\text{Speed of light in medium 1}} = \frac{v_2}{v_1}$$

#Absolute Refractive Index: -

If medium 1 is vacuum or air, then the refractive index of medium 2 is considered with respect to vacuum. This is called the **absolute refractive index** of the medium.

$$n_m = \frac{\text{Speed of light in air}}{\text{Speed of light in the medium}} = \frac{c}{v}$$

#Relative Refractive Index in terms of Absolute Refractive Index: -

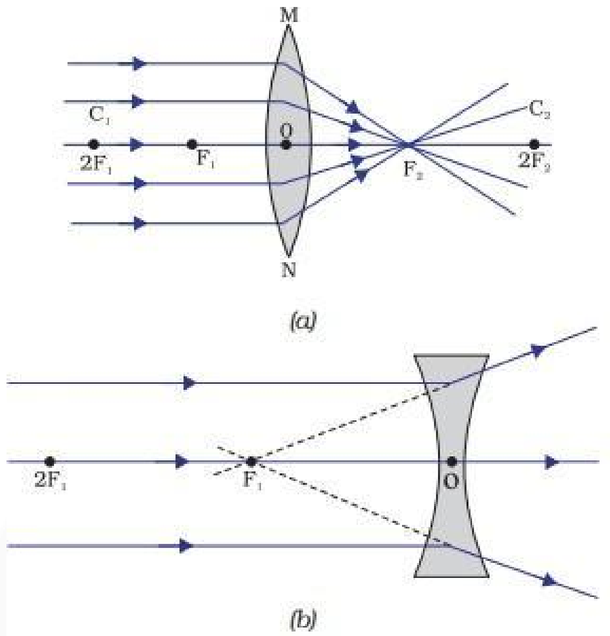
The refractive index of medium1 with respect to medium 2 can be given by (Fig.6)

$$n_{12} = \mu_1/\mu_2$$

Note: -The ability of a medium to refract light is also expressed in terms of its optical density. Optical density has a definite connotation. It is not the same as mass density. We have been using the terms ‘rarer medium’ and ‘denser medium’ in this Chapter. It actually means ‘optically rarer medium’ and ‘optically denser medium’, respectively.

REFRACTION THROUGH SPHERICAL LENSES

- Convex (or Double Convex) lens is converging and Concave (or Double Concave) is diverging lens.



(a) Converging action of a convex lens, (b) diverging action of a concave lens

Focal length in case of convex lens is taken as +ve , and

Focal Length in case of concave lens is taken as -ve.

Terms Related to Lens: -

Optical Centre (O)- Geometrical centre of lens

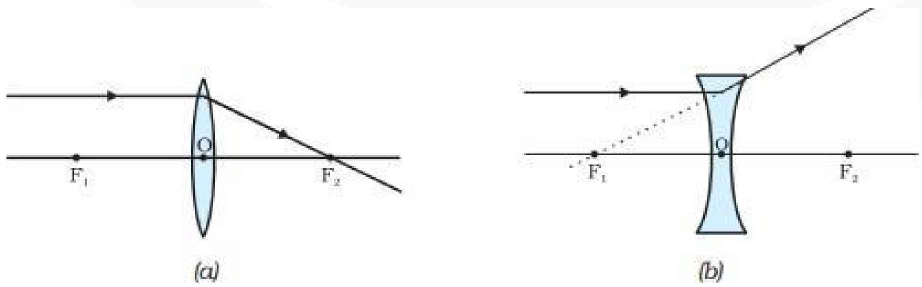
Centre of Curvature(C/ 2F) - Centre of the sphere through which the lens is formed

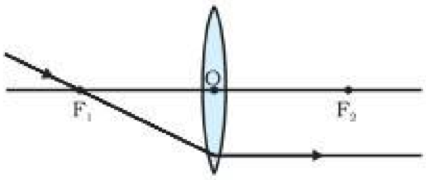
Principal Axis – The line passing through the optical centre and centre of curvature.

Principal Focus(F) - The point on principal axis at which light rays parallel to axis meet or appear to meet after refraction.

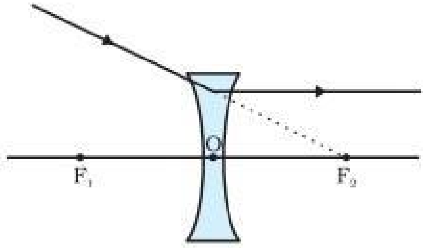
IMAGE FORMATION THROUGH LENES

Options to take rays passing through well defined paths for convex and concave lenses:-

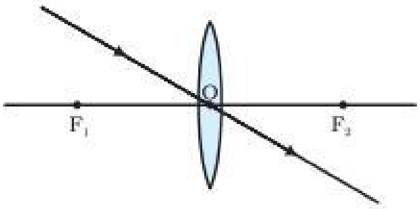




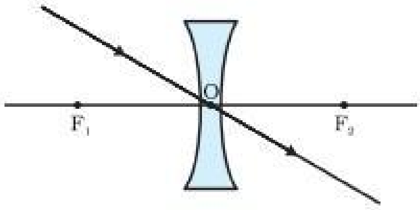
(a)



(b)



(a)

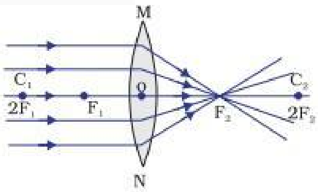


(b)

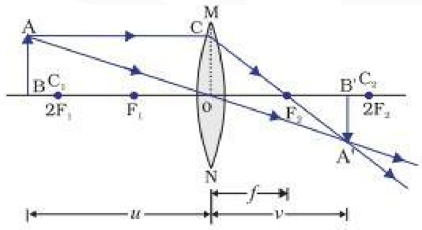
Note :- Out of these three options we can take any two to draw the ray diagram for image formation.

Image Formation for Convex Lens

There are 6 Possible positions of the object and their respective images: -



(a)



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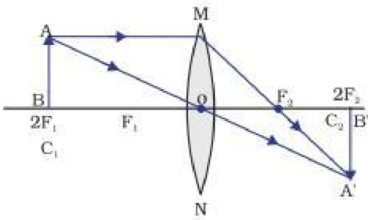
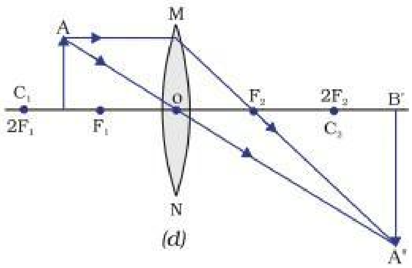
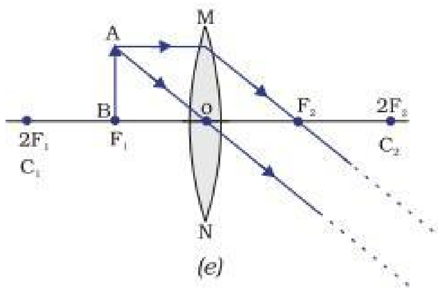


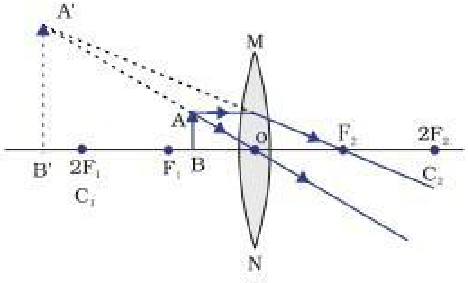
(c)



(d)



(e)

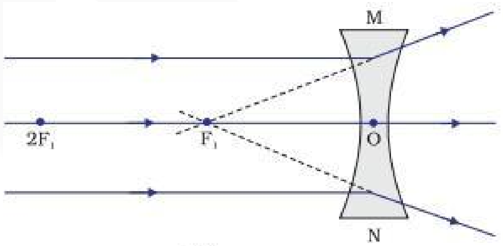


(f)

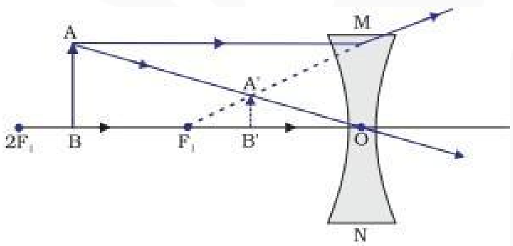
Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_2	Highly diminished, point-sized	Real and inverted
Beyond $2F_1$	Between F_2 and $2F_2$	Diminished	Real and inverted
At $2F_1$	At $2F_2$	Same size	Real and inverted
Between F_1 and $2F_1$	Beyond $2F_2$	Enlarged	Real and inverted
At focus F_1	At infinity	Infinitely large or highly enlarged	Real and inverted
Between focus F_1 and optical centre O	On the same side of the lens as the object	Enlarged	Virtual and erect

Image Formation through Concave Lens

There are only 2 possible positions of the object and their respective images:-



(a)



(b)

Position of the object	Position of the image	Relative size of the image	Nature of the image
At infinity	At focus F_1	Highly diminished, point-sized	Virtual and erect
Between infinity and optical centre O of the lens	Between focus F_1 and optical centre O	Diminished	Virtual and erect

Lens Formula :-

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

Where v = image distance U=

object distance F=

focal length

Magnification :-

$$m = \frac{\text{Height of the Image}}{\text{Height of the object}} = \frac{h'}{h}$$ ______ (i)

$$\text{Magnification } (m) = h'/h = v/u$$ ______ (ii)

Sign Convention for Spherical Lenses :-

Every point is similar as Sign Convention of Spherical Mirrors except we measure all distances (u, v, f)from optical centre.

Power Of Lens : -

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

S.I. Unit of power of lenses is Dioptre 'D' when Focal Length is taken as meter 'm'.

Power of Convex Lens is taken as +ve and Concave Lens is –ve.

Comination of lenses and their combined power when they are attached with each other: -

$$P = P_1 + P_2 + P_3 + \ldots$$