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S.Y. B.Sc. Physics Sem IV. (CBCS pattern)

Paper II- PHY242 Optics

Unit-1 Geometrical Optics

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1. Geometrical Optics

Optics is a branch of physics which deals with nature properties and effect of light. It consists of Geometrical optics, physical Optics and Quantum Optics.

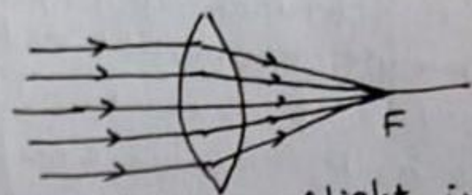
In Geometrical optics we come across formation of images by mirrors, lenses and prism. The physical optics covers the phenomenon of interference, diffraction, polarization and double refraction etc. They are described on the basis of wave nature of light. Quantum optics treats light as a particle called photon. It covers phenomena like photoelectric effect, Compton effect.

* Lenses: Thin and Thick.

A lens is a portion of transparent material bounded by two curved surfaces or by one curved and other plane surface. The curved surfaces of commonly used lenses are mostly spherical and sometimes cylindrical.

Lenses are classified into two groups: (a) Converging or convex
(b) diverging or concave

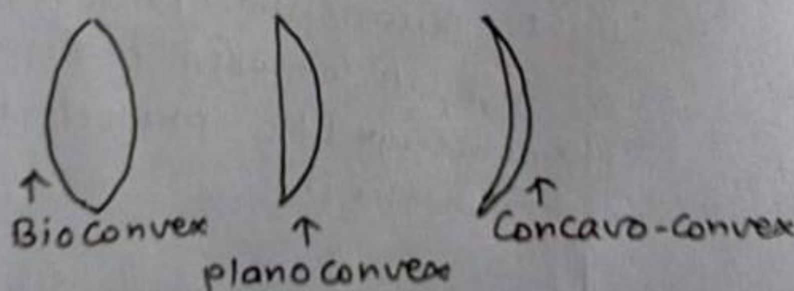
(a) Converging or Convex lenses:



A parallel beam of light incident on a convex lens makes all rays to converge at a point after refraction.

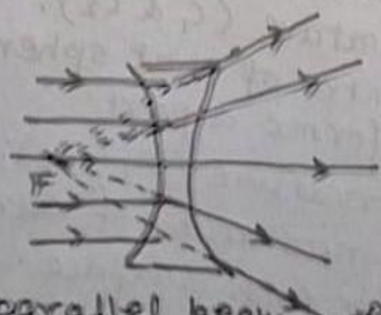
Types:

1. Bi-Convex or Double Convex lens.
2. Plano-convex lens
3. Concavo-Convex lens.



It is thicker at the centre than periphery.

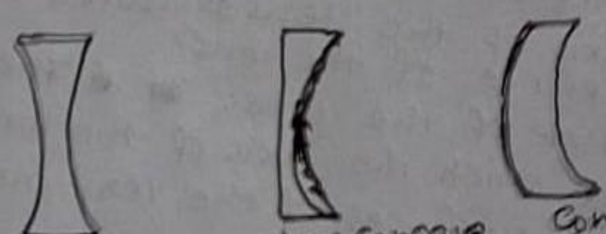
(b) Diverging or Concave lens.



A parallel beam of light incident on a Concave lens makes all rays to diverge after refraction.

Types:

1. Bi-Concave or Double concave
2. plano-concave lens
3. Convexo-concave lens.



Bi concave plano Concave Convexo-Concav

It is thinner at the centre than peripher

*

1. Centre of curvature (C_1 & C_2):
It is the centre of that sphere of which the surface forms a part.

2. Radius of curvature (R_1 & R_2):
There are two radii of curvature of a lens, one for each surface.

3. Axis of the lens:
It is a line passing through the centres of curvature of both the faces of a lens.

4. Optical centre (C): The point of intersection of principle plane with the axis of the lens is called optical centre of the lens.

5. Pole of the lens: The points at which the axis of the lens cut the surfaces of the lens are called the poles of the lens.

6. Principal focus (F):
In case of convex lens, the beam converges and meets at a point F on the principal axis after refraction through the lens.
In case of a concave lens, the beam diverges and appears to come from point F after refraction through lens. This point, in both cases is called principal focus of the lens.

Thick & Thin lenses:

When the distance between the poles of the two surfaces of the lens is very small compared to the radii of curvature of the surfaces, the lens is called a thin lens.

Sign convention:

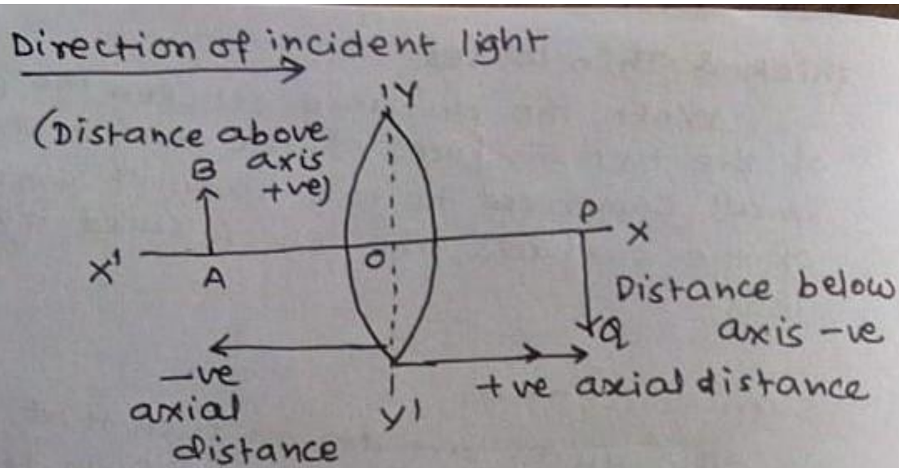
1. All figures are drawn such that, the incident ray travels from left to right and object should be placed to the left of the lens.

2. All distances are measured from the optical centre of the lens.

3. Distances measured to the left of pole or optical centre are negative and those to the right are positive.

4. Distances measured above the axis are positive and below the axis are negative.

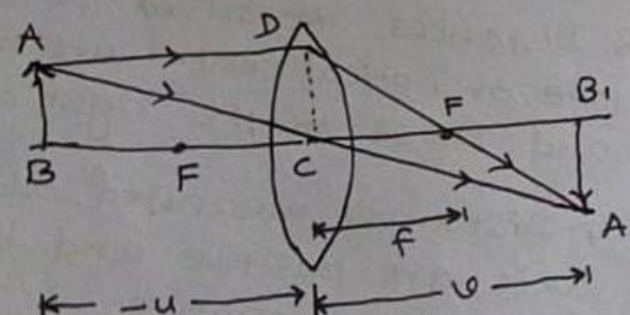
5. An angle which a ray makes with the axis of the lens is taken as positive when the axis is to be rotated through an acute angle in anticlockwise direction to make it coincide with the ray.



(AB → +ve, PQ → −ve, OA → −ve, OP → +ve)

* Thin lens : lens equation

Consider the following diagram...



AB → object, A_1B_1 → real image

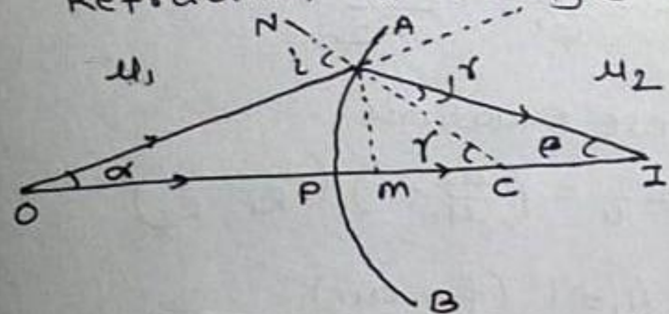
For this situation....

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

is called lens formula

* Lens maker's equation:

Refraction at a single curved surface-



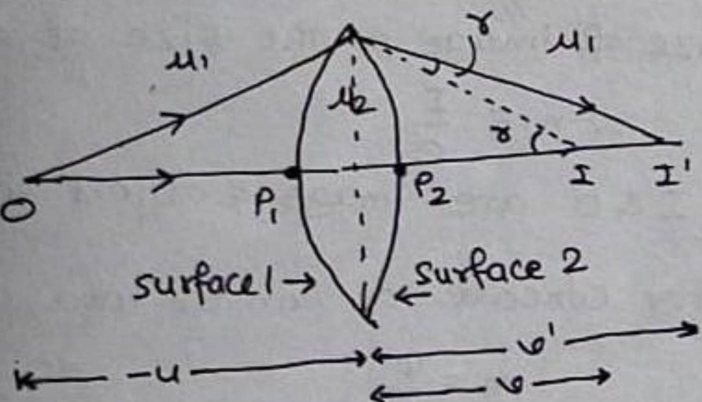
O → point object, I → real image

From this . . .

$$\frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}$$

where μ_1 & μ_2 are two refractive indices.

*Lens maker's formula:



Refraction at surface 1 gives

$$\frac{\mu_2}{v'} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R_1}$$

$$\frac{\mu_2}{v'} = \frac{\mu_1}{v}$$

$$\frac{1}{v} - \frac{1}{u} = \left(\frac{\mu_2}{\mu_1} - 1\right)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

with $\mu_1 = 1$ (for air)

$$\boxed{\frac{1}{v} - \frac{1}{u} = (\mu - 1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)}$$

It is lens maker's formul

Linear magnification: It is the ratio of size of image to the size of object.

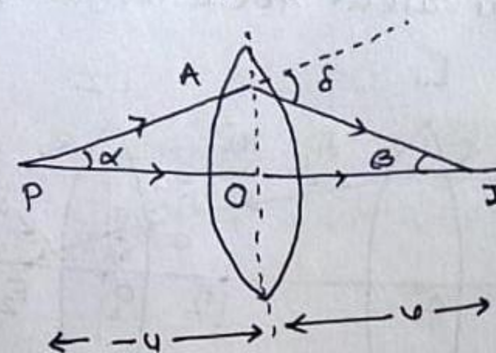
O

For concave or convex lens,

$$m = \frac{}{u}$$

(It is true for real & virtual images)

* Deviation by a thin lens:



$$\delta = \alpha + \beta \quad \& \quad OA = h$$

$$\therefore \delta = \frac{h}{OP} + \frac{h}{OI} = h\left(\frac{1}{v} - \frac{1}{u}\right)$$

$$\delta = \frac{h}{f} \quad \left(\because \frac{1}{f} = \frac{1}{v} - \frac{1}{u}\right)$$

* Power of a thin lens:

It is also called the optical power of the lens.

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

unit of f is meter, unit of optical power is $\frac{1}{m}$ or m^{-1}

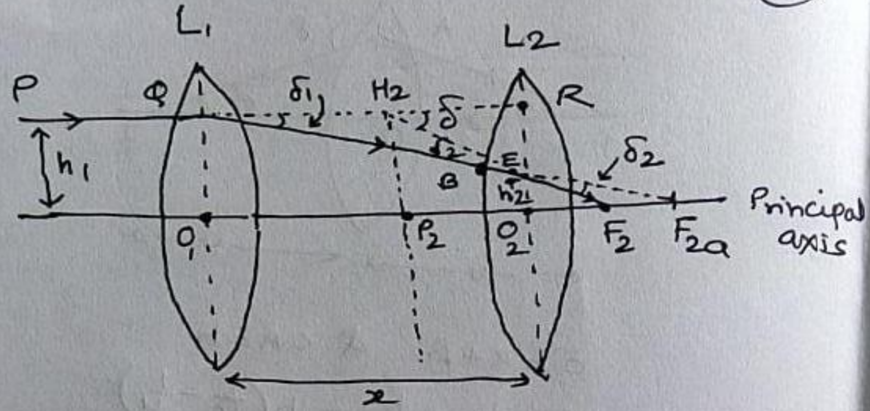
This unit is called diopter (D).

$$\therefore 1D = \frac{1}{m}$$

For a pair of lenses in contact, the power of combination is sum of the two powers of lenses.

$$\therefore P_c = P_1 + P_2$$

* Equivalent focal length of two thin lenses.



From diagram ---.

$O_1Q = h_1$, $O_2E = h_2$

$\delta_1 = \frac{h_1}{f_1}$ $\quad (f_1 = O_1F_{2a})$

$\delta_2 = \frac{h_2}{f_2}$

$\delta = \delta_1 + \delta_2$

$\therefore \delta = h_1/f$ $\quad$ ($f \rightarrow$ focal length of combination)

$\therefore \frac{h_1}{f} = \frac{h_1}{f_1} + \frac{h_2}{f_2}$

gives

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2}$$

$$\therefore \frac{1}{f} = \frac{f_1 + f_2 - x}{f_1 f_2}$$

$$\text{or } f = \frac{f_1 f_2}{f_1 + f_2 - x} = \frac{f_1 f_2}{\Delta}$$

But power of lens in diopters $p = \frac{1}{f \text{ in meter}}$

$$\therefore \; P = P_1 + P_2 - x(P_1 P_2)$$

is the power of combination of lenses L_1, L_2

If L_1 & L_2 are in contact, $x = 0$

$$\therefore \; P = P_1 + P_2.$$

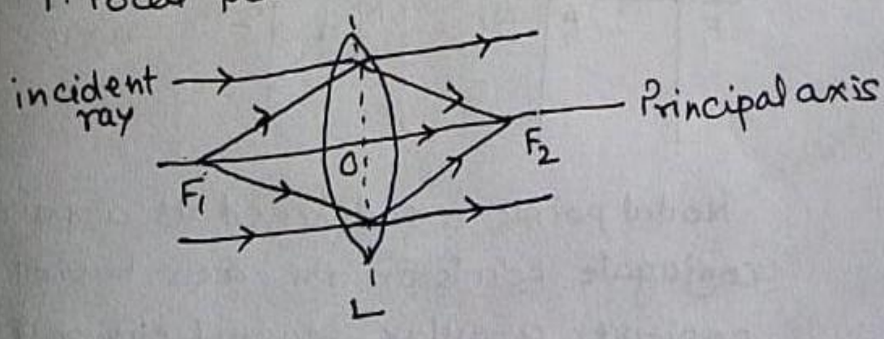
$$\text{or} \quad \frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

* Cardinal points:

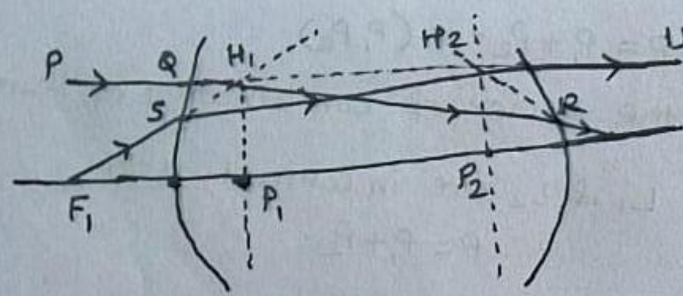
The following are the cardinal points in an optical system.

1. Two focal points (F_1 & F_2)
2. Two principal points (P_1 & P_2)
3. Two nodal points (N_1 & N_2)

1. Focal points:



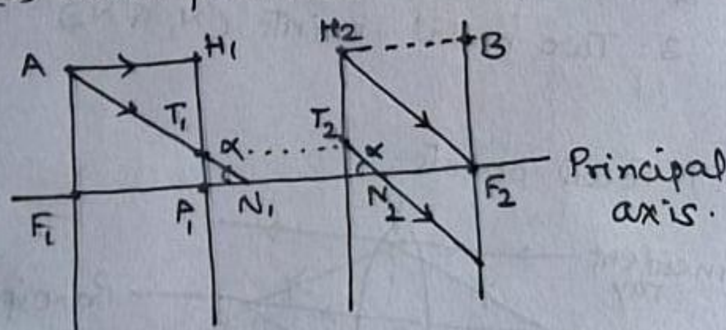
(2) Principal points & principal planes-



A plane passing through pt. H_1 and perpendicular to principal axis is called first principal plane. and the point of intersection with principal axis is called first principal point P_1.

∴ second principal point is P_2.

(3) Nodal points & nodal planes:



Nodal points are defined as a pair of conjugate points on the axis having unit positive angular magnification.

$P_1N_1 = P_2N_2 = 0$ (for same medium on both sides of lens)

∴ Principal points coincide with nodal points. N_1 & N_2

* Cardinal points for a optical system of two thin lenses seperated by a finite distance:

(1) β represents the distance of second principal point of equivalent lens from the ~~first~~ second lens L_2.

$$\therefore \beta = -\frac{xf}{f_1}$$

$x \rightarrow$ distance of seperation of two lenses

✓second principal point: P_2

is situated at a distance $x\left(1-\frac{f}{f_1}\right)$ to the right of first lens.

(2) Position of first principal point:

$$\alpha = \frac{xf}{f_2}$$

This point P_1 of the equivalent lens is situated at a distance $\frac{xf}{f_2}$ from the first lens and is measured to the right of lens L_1