DATE	B.Sc(H)–II	* PHYSICS *	By. Dr. M. K. THAKUR
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LECTURE SERIES-4

CARDINAL POINTS:- The study of refraction of light by the Combination of Lenses can be done by considering the refraction of each lens successively but it is extremely simplified by introducing few points in the system. With the help of these points we can treat the system of two or more lenses as a single lens by applying elementary rules and relations applicable to a single lens, the refraction through combination can be directly studied. These points are called the Cardinal points. There are six points for an optical system. They are known as two focal points, two principle axis and two nodal points.

(i) **FOCAL POINTS:–** The rays parallel to principle axis is incident on system of Lenses, after refraction meet at the point on principle axis is called second focal point. If rays from any point become parallel to principal axis after refraction, then that point is called the first focal point. In Fig. (1) point F_2 shows that second focal point while point F_1 show that first focal point

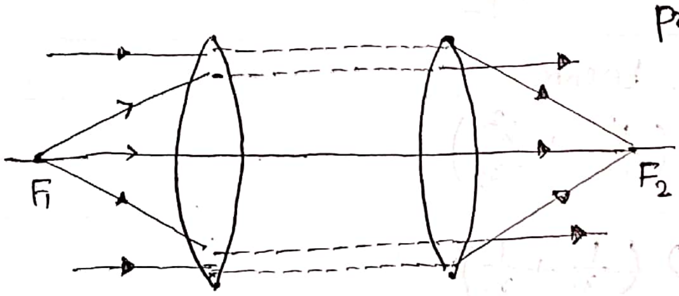

Fig. (1)

(ii) **PRINCIPAL POINTS:–** The principal points are a pair of conjugate points on the principal axis of the optical system.
In Fig. (2) An incident ray PQ parallel to the principal axis, after refraction through the optical system, passes through the second focal point F_2. The incident emergent rays. When produced intersect at A_2. The plane through A_2 and perpendicular to the axis is called the Second principal plane and its point of

intersection with axis, H_2 is called the second principal point.

Similarly, the incident RS passing through the first focal point F_1 and the corresponding emergent ray R'S' parallel to the axis. When produced, intersect at A_1. The plane through A_1 and perpendicular to the axis is called first principal plane and its point of intersection with the axis H_1, is called the first principal point.

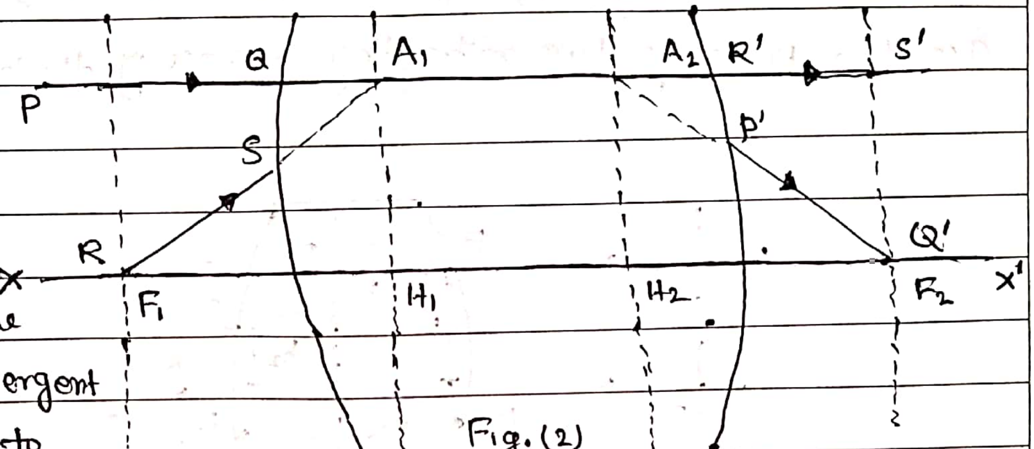

Fig.(2)

(iii) **NODAL POINTS** :- The nodal points are a pair of conjugate point on the principal axis of the system. In Fig.(3) XX' is the principal axis of an optical system and H_1, H_2, F_1, F_2 are the principal and focal points of the system. The object ray M_1N_1 is

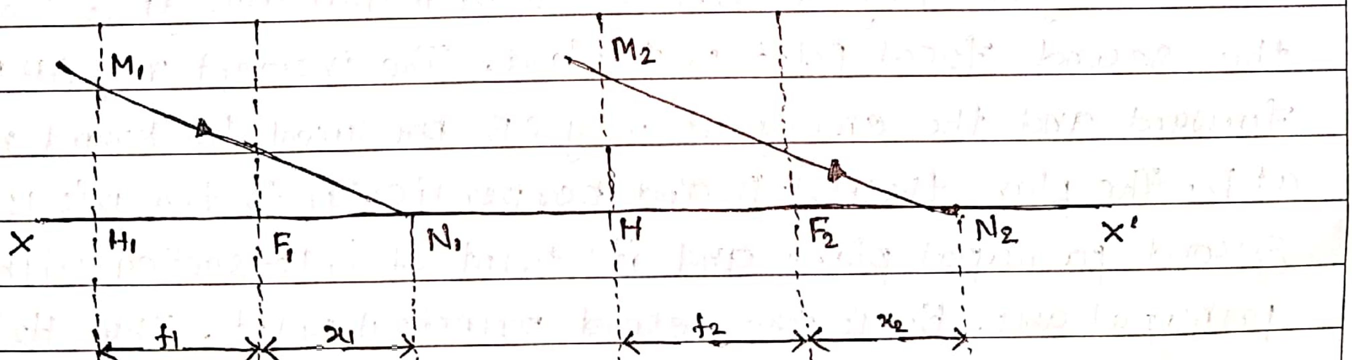

Fig.(3)

parallel to emergent ray M_2N_2. Thus N_2 is an image of N_1. and N_1 and N_2 are nodal point. The planes through N_1 and N_2 are perpendicular to axis and are called nodal planes.

Teacher's Signature:____________

THICK LENS FORMULA:- Let us consider a convex lens of thickness t and refractive index μ placed in air. Let R_1 and R_2 be the radius of curvatures of the faces of the lens. P_1 and P_2 are the poles of two refracting surface of the lens as shown in fig.(1)

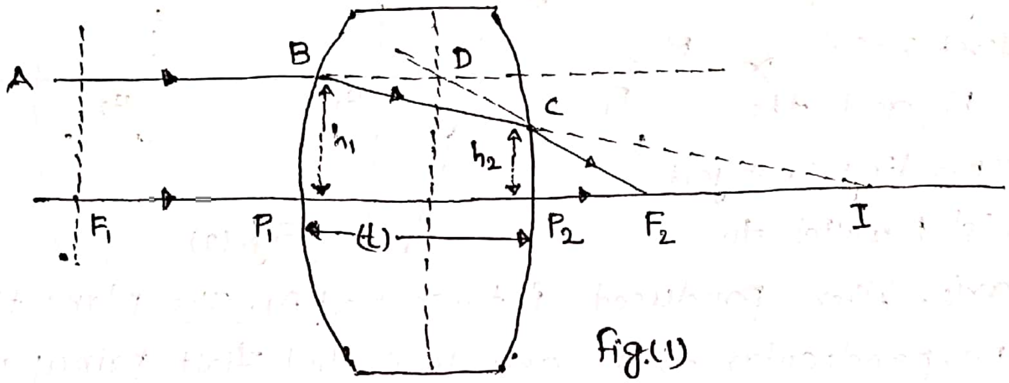

fig.(1)

Let a ray AB parallel to principal axis be incident on the first surface at a height h_1 above the axis. After refraction at the first it follows the path BC in the lens and meets the second surface at height h_2 above the axis. This ray, if produced forward, would meet the axis at I, which serves as virtual object for the second surface. After refraction at the second surface, the emergent ray intersects the principal axis at F_2 which is the second focal point of the lens. The incident ray AB produced forward and the emergent ray CF_2 produced backward meet at D. The plane through D and perpendicular to the axis is the second principal plane and its point of intersection with the principal axis. H_2 is the second principal point. Thus H_2F_2 is the focal length f of the lens.

Now, from the formula of refraction at single surface is

$$\frac{\mu_2}{v} - \frac{1}{u} = \frac{\mu - 1}{R} \quad \left[\text{since } \frac{\mu_2}{v} - \frac{\mu_1}{u} = \frac{\mu_2 - \mu_1}{R}\right]$$

Here for refraction at the first surface, we have

$u = \infty$, $v = P_1I$ and $R = R_1$

$$\therefore \frac{\mu}{P_1I} - \frac{1}{\infty} = \frac{\mu - 1}{R_1}$$

$$\text{or} \quad \frac{1}{P_1I} = \frac{(\mu-1)}{\mu R_1} \quad \text{——— (1)}$$

For refraction at the second surface (i.e from lens to air) we have

$u = P_2I$, $v = P_2F_2$ and $R = R_2$ and μ will be replaced by $1/\mu$

$$\therefore \frac{1/\mu}{P_2F_2} - \frac{1}{P_2I} = \frac{1/\mu - 1}{R_2} = \frac{-(\mu-1)}{\mu R_2}.$$

$$\text{or} \quad \frac{1}{\mu P_2F_2} - \frac{1}{P_2I} = -\frac{(\mu-1)}{\mu R_2}$$

$$\text{or} \quad \frac{1}{P_2F_2} - \frac{\mu}{P_2I} = -\frac{(\mu-1)}{R_2}$$

$$\text{or} \quad \frac{1}{P_2F_2} = \frac{\mu}{P_2I} + \frac{(1-\mu)}{R_2} \quad \text{——— (2)}$$

From similar ΔDF_2H_2, CF_2P_2 and from similar ΔBIP_1, CIP_2 we has

$$\frac{H_2F_2}{P_2F_2} = \frac{h_1}{h_2} = \frac{P_1I}{P_2I}$$

$$\text{or} \quad \frac{1}{P_2F_2} = \frac{1}{H_2F_2} \cdot \frac{P_1I}{P_2I} = \frac{1}{f} \cdot \frac{P_1I}{P_2I} \quad \text{——— (3)}$$

Substituting the value of $\frac{1}{P_2F_2}$ in eqn (2), we have

$$\frac{1}{f} \cdot \frac{P_1I}{P_2I} = \frac{\mu}{P_2I} + \frac{(1-\mu)}{R_2}$$

$$\text{or} \quad \frac{1}{f} = \frac{\mu}{P_1I} + \frac{P_2I}{P_1I} \cdot \frac{(1-\mu)}{R_2}$$

But from the figure, $P_2I = P_1I - P_1P_2 = P_1I - t$

$$\therefore \frac{1}{f} = \frac{\mu}{P_1I} + \left(\frac{P_1I - t}{P_1I}\right)\left(\frac{1-\mu}{R_2}\right)$$

$$= \frac{\mu}{P_1I} + \left(1 - \frac{t}{P_1I}\right)\left(\frac{1-\mu}{R_2}\right)$$

But from equ^n (2)

$$\frac{1}{P_1I} = \frac{(\mu-1)}{\mu R_1}$$

$$\therefore \frac{1}{f} = \mu\left(\frac{\mu-1}{\mu R_1}\right) + \left\{1 - t\left(\frac{\mu-1}{\mu R_1}\right)\right\}\left(\frac{1-\mu}{R_2}\right)$$

$$= \frac{(\mu-1)}{R_1} - \frac{(\mu-1)}{R_2} + \frac{t(\mu-1)^2}{\mu R_1 R_2}$$

$$\text{or} \quad \frac{1}{f} = (\mu-1)\left\{\frac{1}{R_1} - \frac{1}{R_2} + \frac{t(\mu-1)}{\mu R_1 R_2}\right\} \quad \text{—— (4)}$$

This is thick lens formula.

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