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1.Learning outcome

In this module

- We shall learn the different types of cardinal points.
- We shall learn study these cardinal points with its ray diagram

2.Introduction- Cardinal points

In the derivation of various lens formulae, the lens is assumed to be thin, but in case of a thick lens or a system of lenses (two or three in contact), the assumption is no more true and hence the lens formulae cannot be used.

The scientists Gauss and Listing in 1841 solved this difficulty and proved that thick lens can be treated as a single unit and same formulae of a thin lens can be applied by introducing three pairs of points and these are:

(i) the pair of principal focii and focal planes,

(ii) the pair of principal points and principal planes,

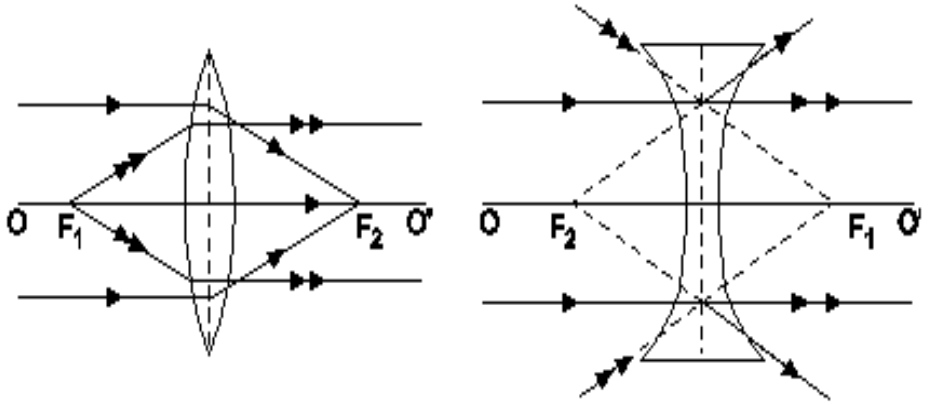
(iii) the pair of Nodal points and Nodal planes.

Thus, there are six such fixed points known as cardinal points of an optical system.

3. Principal focii and focal planes

Let us consider an optical system consisting of a thick lens or a number of co-axial lenses either in contact or separated by some distance having its axis OO'.

A set of rays incident on the system parallel to the axis, on refraction through the system converges to (for a converging system) or appears to diverge from (for a diverging system) an axial point F2 on the axis. This point F2 is called the second principal focus.



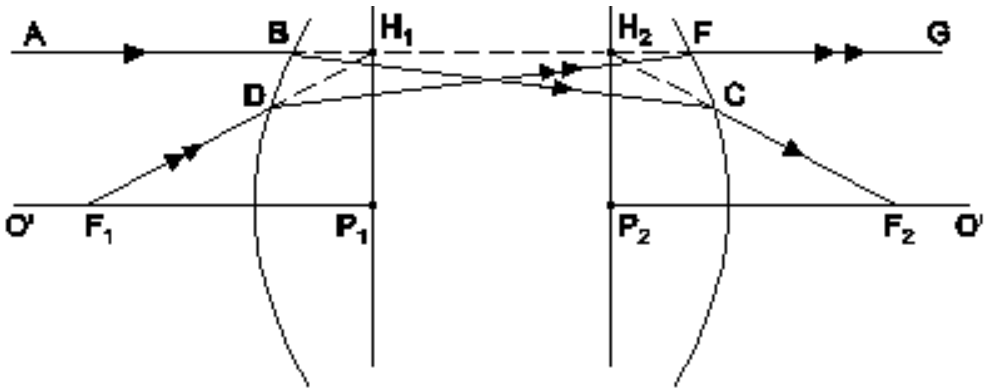
(a) Converging system (b) Diverging system

In a similar way, if the rays starting from (for a converging system) or directed towards (for a diverging system) an axial point F1, after refraction through the system become parallel to the axis OO' then such a point F1 is called first principal focus.

The two points F1 and F2 are called the principal focii or focal points and the planes passing through the principal focii and perpendicular to the axis are called focal planes.

4. Principal points and principal planes

Consider a thick lens having its principal focii F1 and F2. The ray AB is incident at B parallel to the principal axis OO', after refraction emerges along BC and the ray passes to the second principal focus F2. The incident and emergent ray when produced backward intersect at H2.



The plane passing through H2 and perpendicular to the principal axis OO' is termed as second principal plane of a lens. The point of intersection of this plane with the axis at P2 is called second principal point (P2).

Consider another ray F1D through the first principal focus F1 incident at D, after refraction, it emerges along EG parallel to the axis OO'. The rays F1D and EG when produced intersect at H1. The plane perpendicular to the principal axis OO' passing through H1 is called the first principal plane of a lens. The point of intersection of this plane with the axis at P1 is called first principal point (P1).

From Fig. 1.3, we see that any incident ray (AB or F1D) directed towards H1 appears to come from H2 after refraction. Therefore, H2 is the image of H1. Hence H1 and H2 are the conjugate points and the planes H1P1 and H2P2 are pairs of conjugate planes.

$$H1P1 = \quad H2P2$$

$$\text{Hence the lateral magnification} = \frac{\text{Height of the image}}{\text{Height of the object}} = \frac{H_2P_2}{H_1P_2} = +1$$

Thus, the principal plane has lateral magnification = + 1.

Properties:

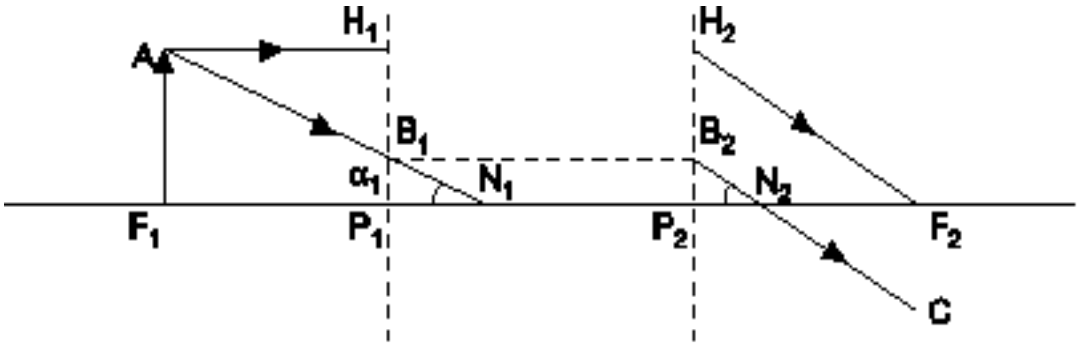
(1) They are two conjugate planes of unit positive lateral magnification.

(2) The distance P1F1 represents the first principal focal length denoted by

F1 and the distance P2F2 represents the second principal focal length denoted by F2.

5. Nodal points and Nodal planes:

Nodal points are defined as a pair of conjugate points on the axis having a unit positive angular magnification. It means that a ray of light directed towards one of these points, after refraction through the optical system appears to proceed at the second point in a parallel direction as shown in Fig. 1.4.



Consider a point in a first focal plane of an optical system. One ray AH_1 is parallel to the axis. Its conjugate ray emerges along H_2F_2 such that

$$H_1P_1 = H_2P_2$$

Another ray AB_1 is parallel to H_2F_2, its conjugate ray B_2C originates from B_2 such that $B_1P_1 = B_2P_2$. B_2N_2 is parallel to H_2F_2. The point of intersection of incident AB_1 and its conjugate emergent ray B_2C with the axis are called the nodal points N_1 and N_2. The planes passing through nodal points perpendicular to the axis are called nodal planes.

6. Summary

I. In an optical system, there are six cardinal points.

II. A pair of principal foci.

III. A pair of principal points and

IV. A pair of nodal points.

V. When all cardinal points are included in an optical system, then difficulty of formula of lanes is solved, so cardinal points are very important in an optical system.

7 . Video

1. https://youtu.be/0z99OFTMEDM
2. https://youtu.be/inHFqCJFs1Q
3. https://youtu.be/kT41TH8jp14

8 . Assessment

1. https://forms.gle/bLFZPpHe7hqRcGMFA