

→ Cardinal points of a thick lens & thick lens formula :

The cardinal points of an optical-system or a thick lens are six in number

- (a) Two focal points.
- (b) Two principal points.
- (c) Two nodal points.

A pair of points lying on the principal axis of optical system and conjugate to points at infinity are called focal points. These are two as shown in the fig (i) & (iv)

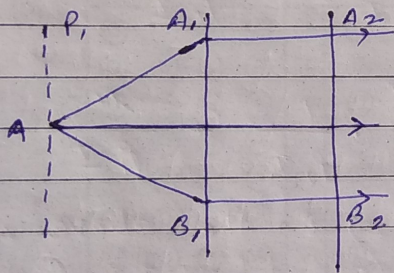


fig (1)

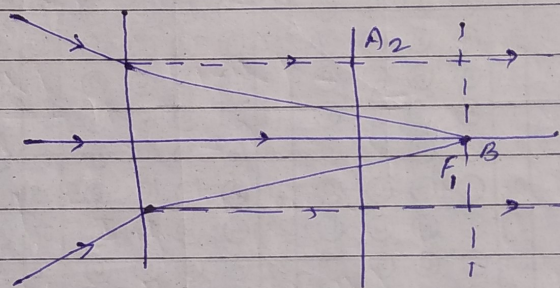


fig. (2)

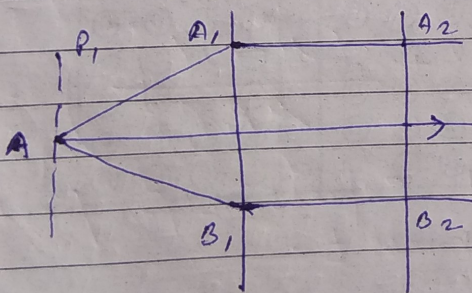
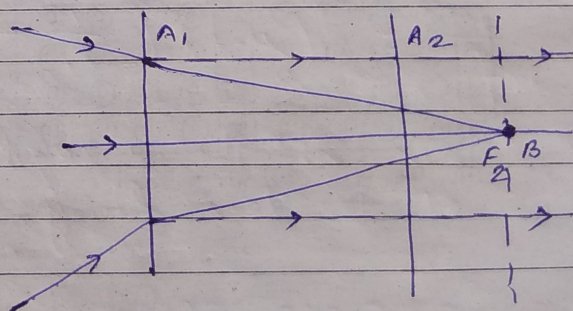


fig (3)



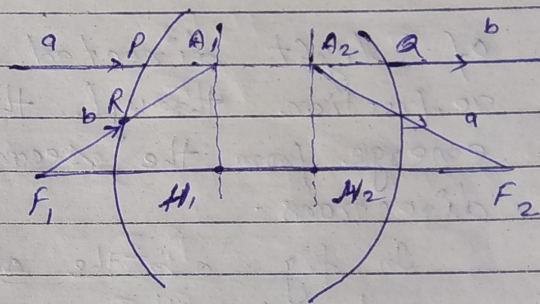
fig(4)

1. First Focal point & First focal plane : → It is the object point on the principal axis for which image point is on the infinity. The plane passing through this and perpendicular to the principal axis.

to the principal axis is focal plane.

The second focal point of an optical system is defined as the image point on the principal axis for which the object lies at infinity.

(2) Principal points:  $\rightarrow$  A pair of conjugate points on the principal axis of the optical system or a thick lens having unit positive linear magnification are called principal points of the optical system of a thick lens.



The points  $H_1$  and  $H_2$  shown in the above fig. are the principal points. It is obvious from this fig. that the incident rays 'a' and 'b' are converging towards point  $A_1$ , and after refraction the corresponding emergent rays appear to diverge from point  $A_2$ . Hence  $A_2$  is the image of  $A_1$ , where  $AH_1 = AH_2$  and both these are  $\perp$  to the principal axis at points  $H_1$  &  $H_2$  respectively. These two points are the principal points and  $A_1H_1$  and  $A_2H_2$  are principal planes.

The main features of these points in the lens are:

(i) If an incident ray passes through a point in the first principal plane at a given distance from the axis, the corresponding emergent ray will certainly pass through a point in the second plane at the same distance from the axis.

(ii) If the medium on the both the sides of the optical system is same, the first and second focal length of an optical system will be equal

$$\text{i.e. } f_1 = f_2$$

③ Nodal points:  $\rightarrow$  A pair of conjugate points on the principal axis of the optical system having unit positive angular magnification are called the nodal points of the optical system.

This simply means that a ray of light directed towards one of these points after refraction through the optical system, will appear to emerge from the second nodal point parallel to the original direction.

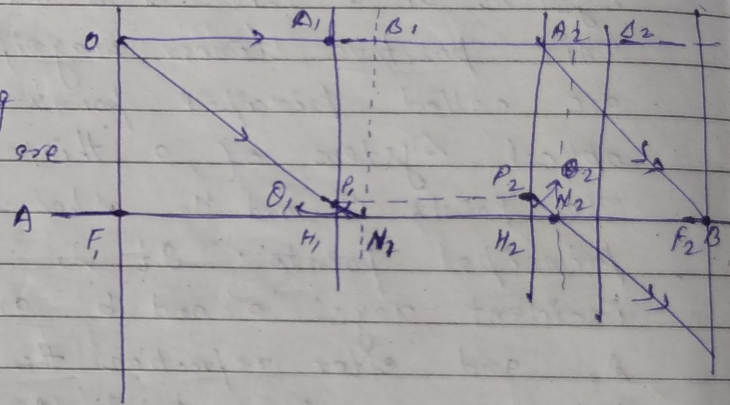
In fig 'o' is the object and 'I' is the corresponding image. The point  $N_1$  &  $N_2$  are two nodal points.

The feature of the two nodal points are

(i)  $\frac{\tan \theta_1}{\tan \theta_2} = 1$

(ii)  $H_1, H_2 = N_1, N_2$  i.e. distance between two nodal points is equal to the distance between two principal points.

(iii) When the medium on both the sides of the optical system is same (let air), the principal points coincides with the nodal points and then these points are then called as the equivalent points.



refraction at 90 degree