Bhartiya Vidya Bhavan's Shri Ishvarlal L. P. Arts-Science and J. Shah Commerce College, Dakor
Dakor - 388225, Dist. – Kheda, Gujarat

B.Sc. (semester -3)

Subject : Physics

Course : USO3CPHY21 OPTICS

UNIT 1: Geometrical Optics/Lect.-3

By

Dr. Sahajkumar A. Gandhi

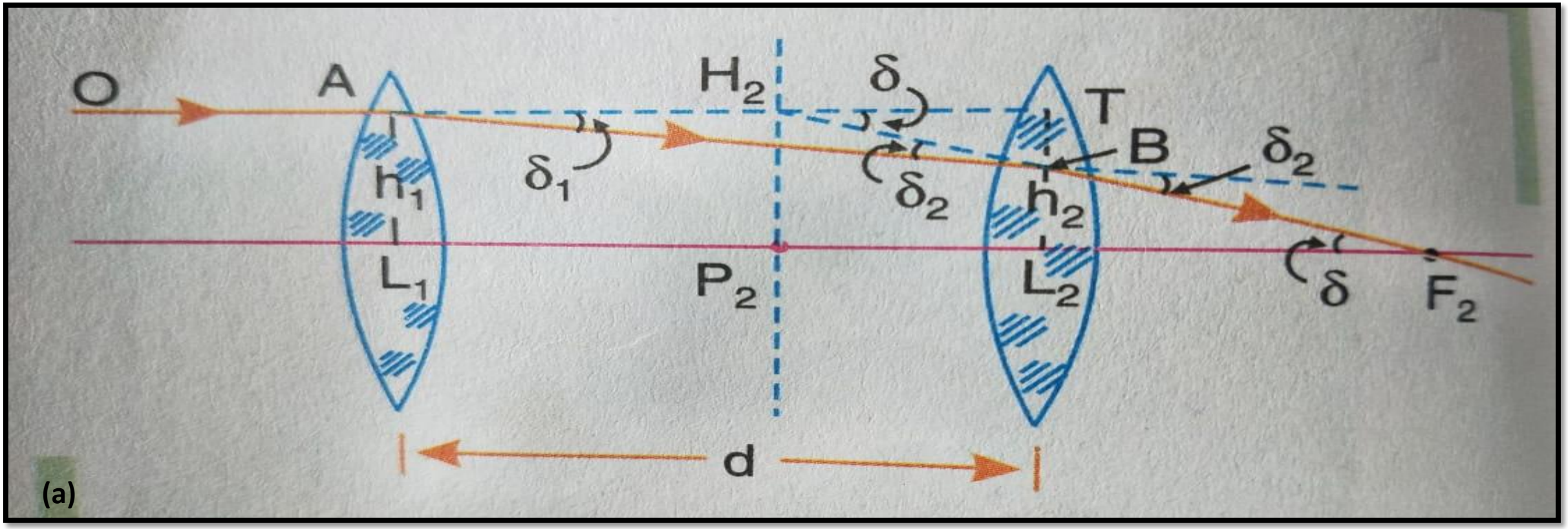
Unit:1 Geometrical Optics

- ✓**Revision – 2nd lecture [Cardinal points and planes of lens system]**
- ✓**Prove that the nodal points are a pair of conjugate points on the axis having unit positive angular magnification.**
- ✓**The distance between two nodal points is always equal to the distance between two principal points.**
- ✓**The nodal points N1 and N2 coincide with the principal points P1 and P2 respectively whenever the refractive indices on either side of the lens are the same.**

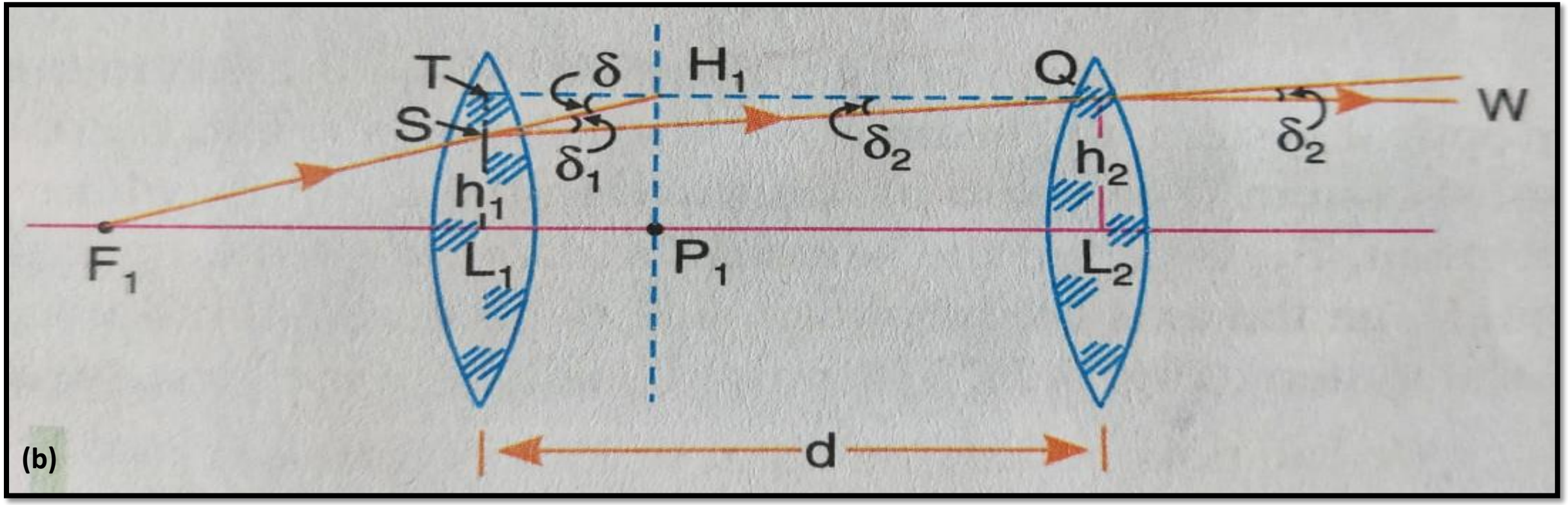
Text Book:

1. A Textbook of Optics
   Subrahmanyam, Brij lal and Avadhnulu
   S Chand Publication (24th Revised addition 2010)

1. Principal points and principal planes



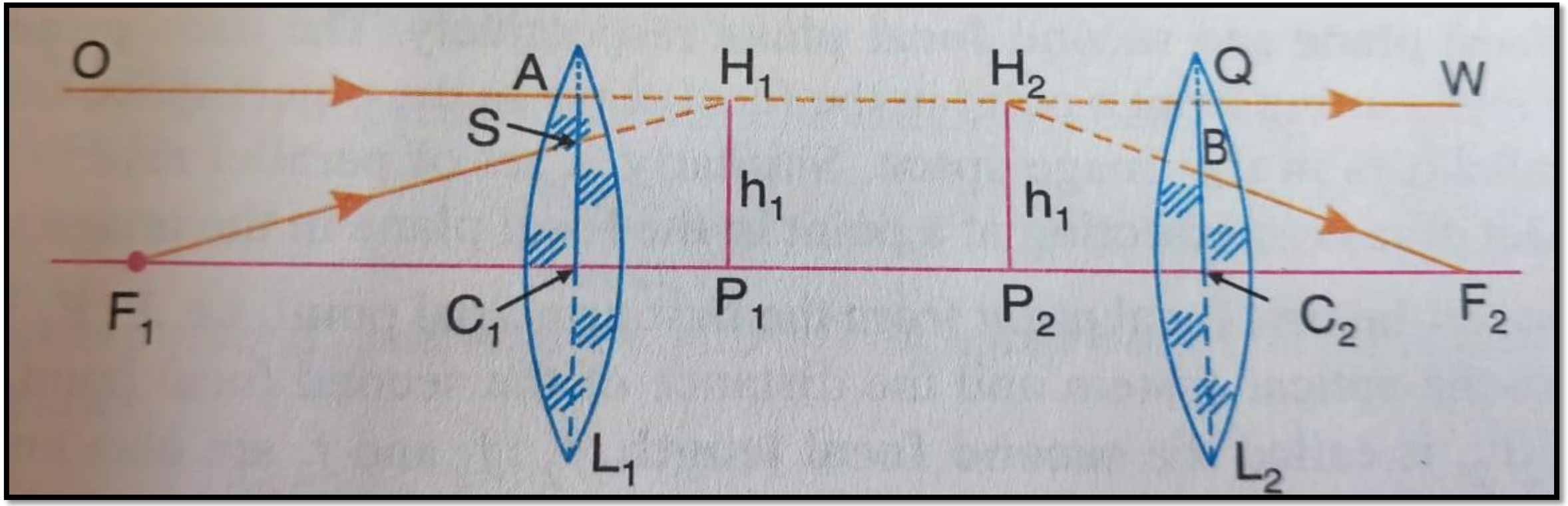
- A ray OA travelling parallel to the principle axis and incident at A is brought to focus at F2 in the **image space** of the optical system as shown in above Figure.
- A plane drawn through the point H_2 and perpendicular to the axis may be regarded as the surface at which refraction take place. This plane is called the principal plane of the optical system.
- H_2P_2 is the principal plane in the image space and is called the second principal plane.
- The point P_2 at which the second principal plane intersects the axis is called the second principal point.



- We can locate the principal plane H1P1 and principal point P1 in the **object space**.
- A plane perpendicular to the axis and passing through H1 is called the first principal plane.
- The point of interaction, P_1 of the first principal plane with the axis is called the first principal point.
- It seen from above figure, that two incidents ray are directed towards H_1 and after refraction seem to come from H_2.
- Therefore H_2 is image of H_1 Thus H_1 and H_2 are the conjugate points and the planes H_1P_1 and H2P2 are a pair of conjugate planes . It is also seen that

$$H_2P_2 = H_1P_1$$

FOCAL POINTS AND FOCAL PLANE



- If a parallel beam of light travelling from the left to the right (in object space) is incident on the optical system, the beam comes together at a point, F_2 on the other side (in image space) of the optical system.
- The beam passes through the point F_2 whatever may be its path inside the system. The point $F_{2,}$ is called the second focal point of the optical system.
- A beam of light passing the point F_1. on the axis of the object side is rendered parallel to the axis after emergence through the optical system (Fig. 5.2). The point F_1, is called the first focal point.

NODAL POINTS AND NODAL PLANES

- Nodal points are points on the principal axis of the optical system where light rays, ***without refraction***, intersect the optic axis.
- In a thin lens the nodal point is the center of the lens. Light passing through the center of a thin lens does not deviate. In an optical system the center separates into two nodal points.
- The planes passing through the nodal points and perpendicular to the principal axis are called the **nodal planes.**
- Whereas the principal planes are planes where all refraction are assumed to occur, the nodal planes are planes where refraction does not take place.

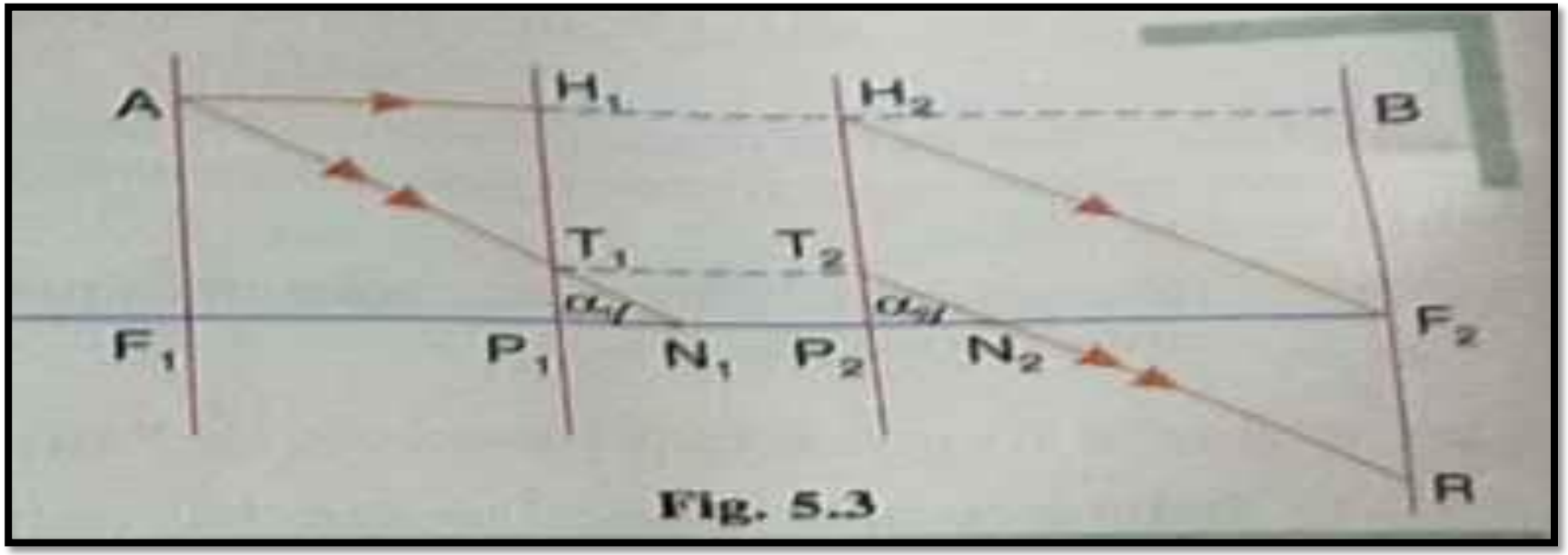


Fig. 5.3

- Fig. 5.3 represents an optical system with the help of its cardinal planes.
- From the Fig 5.3, that a ray of light, AN_1 directed towards one of the nodal points N_1, after refraction through the optical system, along N_1N_2, emerges out from the second nodal point, N_2 in a direction, N_2R. parallel to the incident ray.
- The distances of the nodal points are measured from the focal points.

Prove that the nodal points are a pair of conjugate points on the axis having unit positive angular magnification. [4 marks]

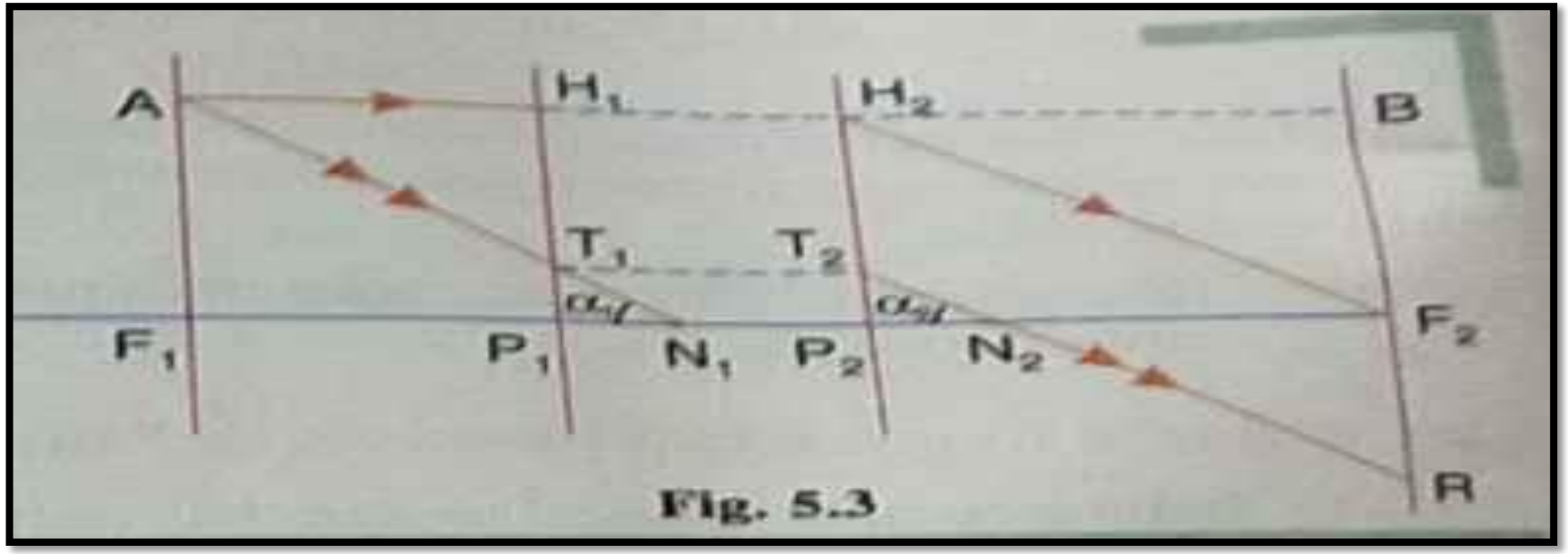


Fig. 5.3

- Let H1P1 and HP2 be the first and second principal planes of an optical system.
- Let AF1 and BF2 be its first and second focal plane respectively.
- Consider a point A situated on the first focal plane. From A draw a ray AH1 parallel to the axis. The conjugate ray will proceed from H2, a point in the second principal plane such that H2P2 = H1P1 and will pass through the second focus.
- Take another ray AT1 parallel to emergent ray H2F2 and incident on the first principal plane at T1. It will emerge out from T2, a point on the second principal plane such that T2P2 = T1P1, and will proceed parallel to the ray H2F2.

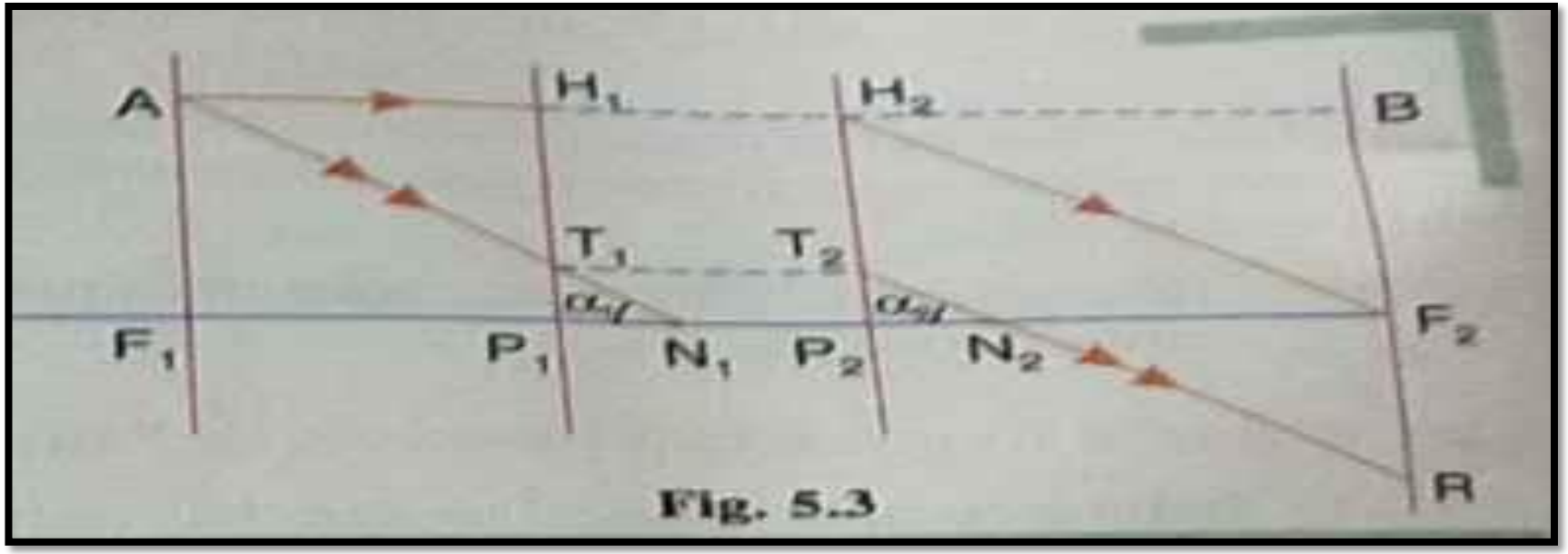


Fig. 5.3

- The point of intersection of the incident ray AT1 and the conjugate emergent ray T2R with the axis give the positions of the nodal points.
- It is clear that the two points N1 and N2 are a pair of conjugate points and the incident ray AN1 is parallel to the conjugate ray T2R.
- Further, $\tan \alpha 1 = \tan \alpha 2$
- The ratio $\frac{\tan \alpha 2}{\tan \alpha 1} = \gamma$ represent **angular magnification.**

$$\frac{\tan \alpha 2}{\tan \alpha 1} = 1$$

- Therefore, *the points N1 and N2 are a pair of conjugate points on the axis having unit positive angular magnification.*

The distance between two nodal points is always equal to the distance between two principal points. [4 marks]

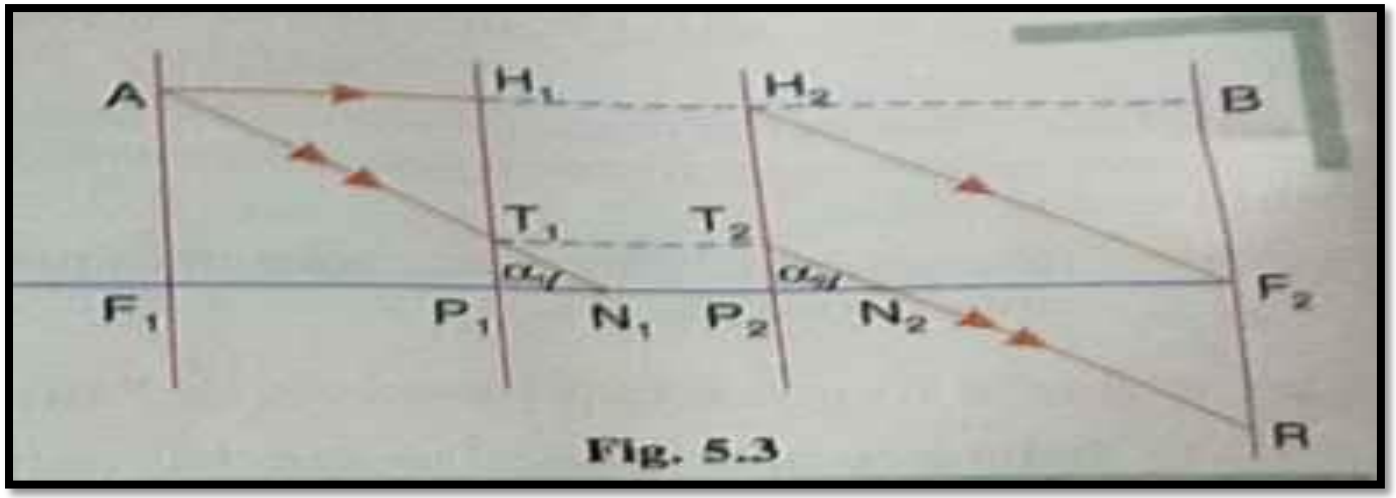


Fig. 5.3

Referring to Fig.5.3, we see that in the right angled Δ^{les} $T_1P_1N_1$ and $T_2P_2N_2$

$$T_1P_1 = T_2P_2$$

$$\angle T_1 N_1P_1 = \angle T_2 N_2P_2 = \alpha$$

Therefore, the two Δ^{les} are congruent.

$$\therefore \quad P_1N_1 = P_2N_2$$

Adding N_1P_2 to both the sides, we get

$$\therefore \quad P_1N_1 + N_1P_2 = P_2N_2 + N_1P_2$$

$$\therefore \quad P_1P_2 = N_1N_2 \qquad (5.2)$$

Thus, *the distance between the principal points N_1 and N_2 is equal to the distance between the principal points P_1 and P_2.*

The nodal points N1 and N2 coincide with the principal points P1 and P2 respectively whenever the refractive indices on either side of the lens are the same. [4 marks]

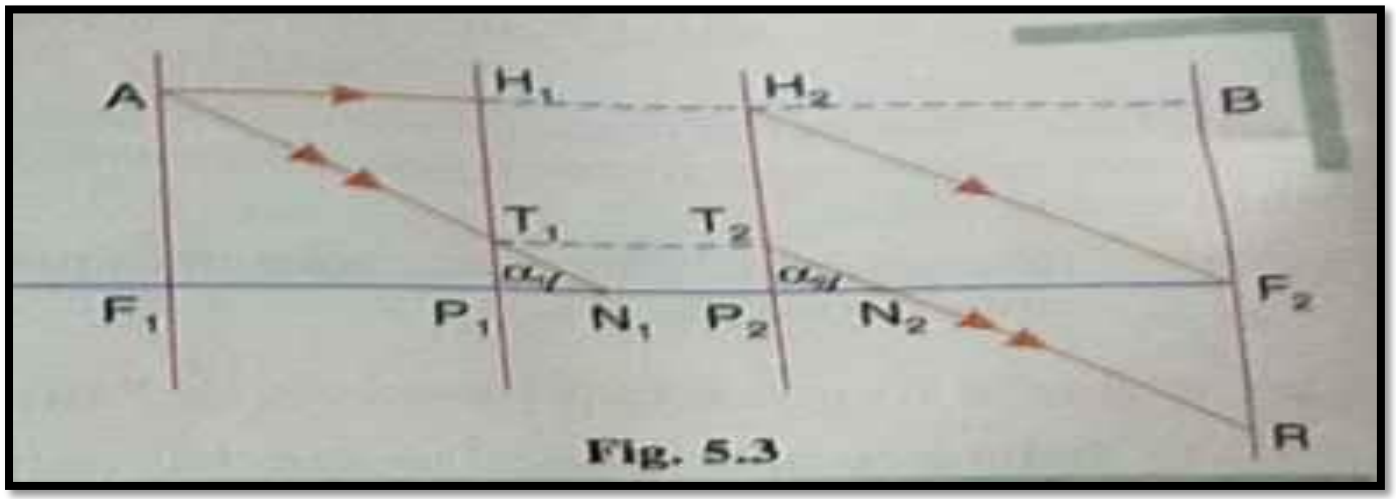


Fig. 5.3

Now consider the two right angled Δ^{les} AF_1N_1 and $H_2P_2F_2$ in Fig.5.3.

$$AF_1 = H_2P_2$$

$$\angle A N_1F_1 = \angle H_2F_2 P_2$$

$\therefore$ The two Δ^{les} are congruent.

$$F_1N_1 = P_2F_2$$

But $$F_1N_1 = F_1P_1 + P_1 N_1$$

$\therefore$ $$F_1P_1 + P_1 N_1 = P_2F_2$$

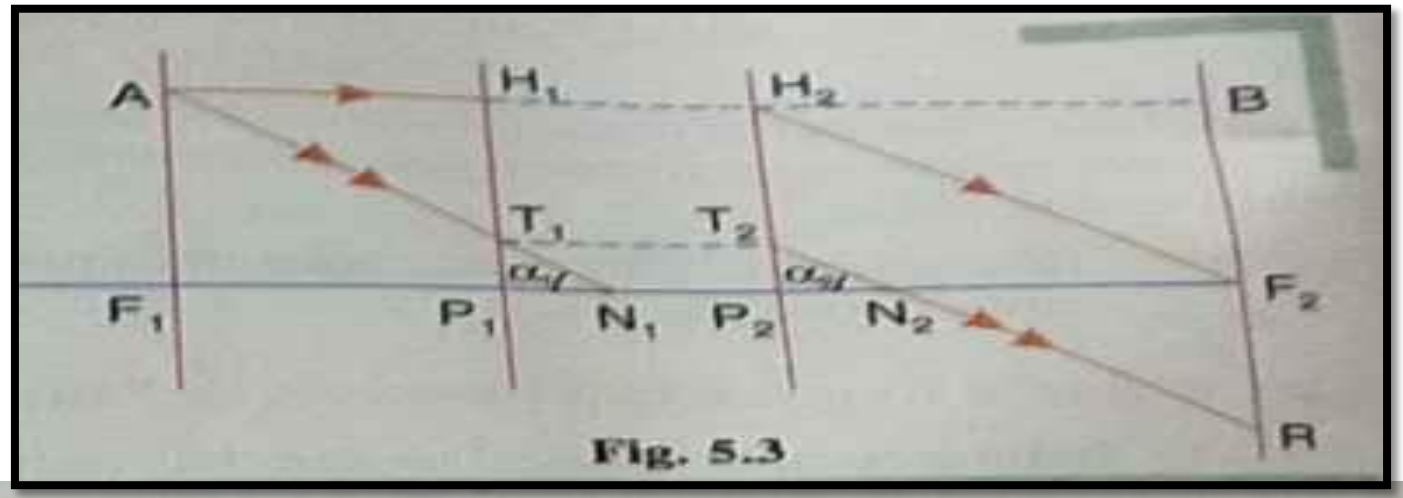


Fig. 5.3

$$\therefore \quad P_1N_1 = P_2F_2 - F_1P_1$$

Also $P_2F_2 = +f_2$ and $P_1F_1 = -f_1$

$$\therefore \quad P_1N_1 = P_2N_2 = (f_1 + f_2)$$

As the medium is the same, say air, on both the sides of the system

$$f_2 = -f_1$$

$$\therefore \quad P_1N_1 = P_2N_2 = 0 \qquad (5.3)$$

Thus, the principal points coincide with the nodal points when the optical system is situated in the same medium.

Do you have Any Questions

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Thank you

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