Experiment No. 6

Object: To verify the expression for the focal length of a combination of two lenses.

Apparatus Required: Two convex lenses of different focal length and an optical bench with four uprights; a lamp of narrow opening, a cross-slit screen, nodal slide assembly and a plane mirror.

Formula Used:

The focal length of a combination of two convex lenses is given by,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

where, f_1 and f_2 are the focal lengths of two convex lenses separately and d is the distance between them when they form combination of lenses.

Procedure:

- Mount a plane mirror, the nodal slide, the cross-slit screen holder and the lamp on the optical bench in such a way that their axis lies along the same horizontal line as illustrated in Figure 1.
- Clamp one convex lens on the lens carriage at the centre of the nodal slide assembly. Adjust the position of the nodal slide until the distance between the lens and screen is approximately the focal length of the lens. Orient the mirror until the light from the object O on the screen, rendered parallel by the lens, is reflected back normally and forms an image I of the object O on the same screen. Move the nodal slide along the bench until the image I is sharply focused.
- The lens carriage is now rotated through a small angle and it will be found that the image shifts sideward's to the right or the left. The lens carriage and the nodal slide upright are then adjusted such that the image remains stationary for a slight rotation of the lens carriage.
- The distance between the screen and the axis of the rotation of nodal slide for no shift in the image measures the focal length of one face of the lens. The focal length of other face can be determined by the turning the nodal slide through 180° and repeating the experiment. The mean of focal length of both the faces is the focal length f_1 of one lens.
- Repeat the above procedure with the other lens and determine the focal length f_2.
- Now clamp both the lenses on the lens carriage at a known separation (d) in such a way that both the lenses are at equidistance from the centre of the nodal slide assembly, shown in Figure 2. Repeat the procedure with the combination of two lenses and determine the focal length F.
- The procedure is repeated at least three times with changing the distance between the lenses.

Observations:

(i) Table for determination of focal length f_1 and f_2 of two convex lenses:

Position of Lamp = …….. cm

Lens	Light incident on	Position of upright of (in cm)		Focal length of the lens = (a – b)	Mean focal length in cm
		Cross-slit (a)	Nodal Slide (b)		
First	One face				f_1 =
	Other face				
Second	One face				f_2 =
	Other face				

(ii) Table for determination of focal length *F* of combination of two convex lenses:

Position of Lamp = …….. cm

Sr. No.	Distance between two lenses *d*, in cm	Light incident on	Position of upright of (in cm)		Focal length of the combined lenses = (*a* – *b*)	Mean focal length *F*, in cm
			Cross-slit (*a*)	Nodal Slide (*b*)		
1	d_1 =	One face				F_1 =
		Other face				
2	d_2 =	One face				F_2 =
		Other face				
3	d_3 =	One face				F_3 =
		Other face				

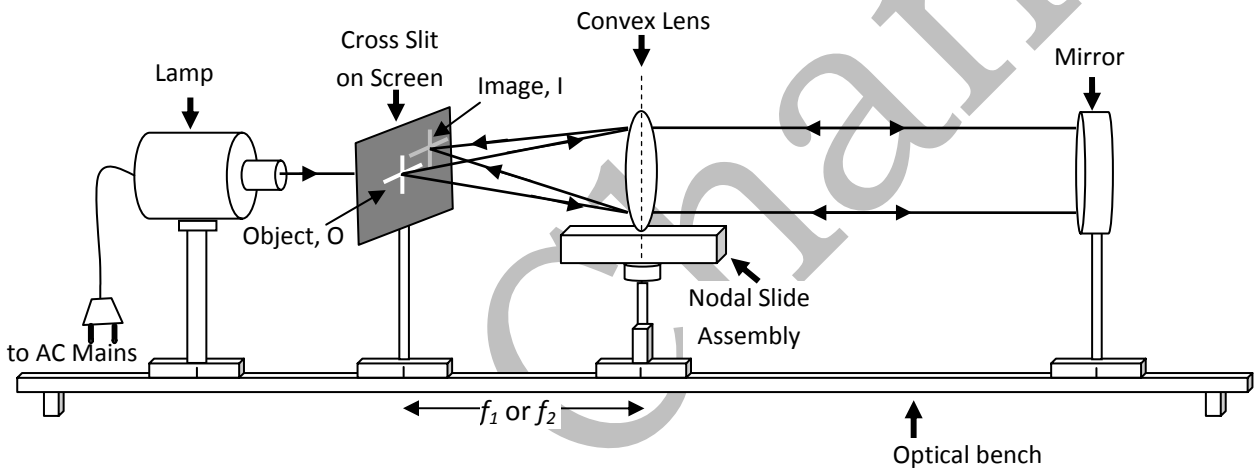

Figure 1: Experimental arrangement to observe focal length f_1 or f_2 of any one convex lens.

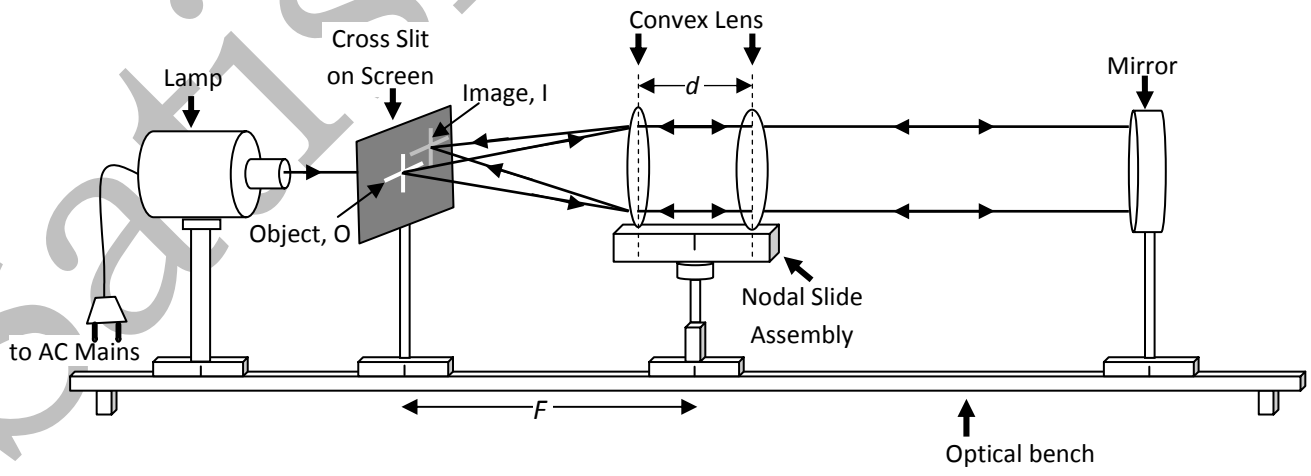

Figure 2: Experimental arrangement to observe focal length *F* of combination of two lenses.

Calculation:

Theoretically, the focal length of a combination of two convex lenses is given by,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$$

where, f_1 and f_2 are the focal lengths of two convex lenses and d is the distance between them. Hence, calculate the value of focal length for different distances using above formula.

Distance, *d*	**Observed focal length (from Table ii)**	**Calculated focal length (from calculation)**
$d_1 =$	$F_1 =$	$F_1' =$
$d_2 =$	$F_2 =$	$F_2' =$
$d_3 =$	$F_3 =$	$F_3' =$

Result: The values of calculated and observed focal lengths of combination of two lenses for each separation are matching nearly. Hence the expression for the focal length of a combination of two convex lenses is verified.

Precautions and Sources of Errors:

(1) The parallax should be removed very carefully and the stationary point is obtained.
(2) All the uprights should be exactly at same height and at same horizontal axis.
(3) The cross-slit must be properly illuminated by the intense light coming from the lamp.
(4) The rotation of the nodal slide carriage about the vertical axis while testing stationary point of the image should not exceed by 5° or so.
(5) Lenses should be of small aperture to get well defined and sharp image on the screen.
(6) The mirror employed must be truly plane mirror.