EXPERIMENT NO.2

NODAL SLIDE EXPERIMENT

OBJECT:

To determine the focal length of the combination of two thin convergent lenses separated by a distance with the help of a Nodal Slide and to verify the formula of the focal length of combination of lenses.

APPARATUS USED:

Nodal – Slide assembly (consisting of an optical bench, plane mirror, cross slit and lamp) and the two given lenses.

FORMULA USED:

The combined focal length of two convex co –axial lens system is determined as

— = — + — - ——

Where

f_1	=	Focal length of first lens
f_2	=	Focal length of second lens
d	=	Distance between the two lenses
and F	=	Combined focal length of co-axial lenses system

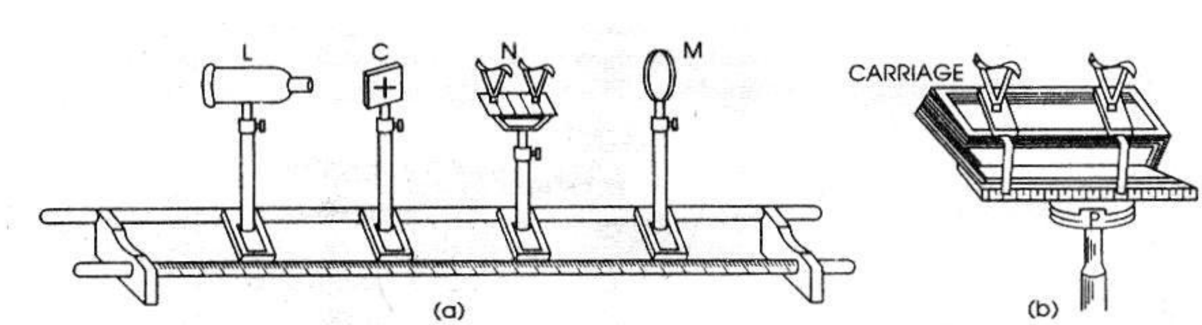

Figure.1 Experimental Arrangement of Nodal Slide Experiment

THEORY:

The focal length of a lens system is the distance between its principal point and the corresponding focal point. The principal points coincide with the corresponding nodal points when the media are the same on both the sides of the system (air). Thus the focal length of the system can be determined by locating a nodal point can be located by using the fact that in case of parallel beam of light incident on a convergent lens system, thus forming an image on a screen in its second focal plane , the image does not shift laterally when the system is rotated about a vertical axis passing through its second nodal point.

Let L_1 and L_2 be the two thin convergent lenses of focal lengths f_1 and f_2 placed coaxially at a distance d apart .Let a ray AB parallel to the axis be incident on the first lens L_1 at a height h_1 above axis . On refraction through the lens it suffers a deviation θ_1 as

$$\theta_1 = \frac{h_1}{f_1} \qquad (\text{As } \tan\theta_1 = \theta_1) \tag{1}$$

When this ray falls on the lens L_2 at a height h_2 it also suffers a deviation as

$$\theta_2 = \frac{h_2}{f_2} \tag{2}$$

Therefore total deviation is given as:

$$\theta = \theta_1 + \theta_2 = \frac{h_1}{f_1} + \frac{h_2}{f_2} \tag{3}$$

Where from geometry of the ray diagram we see that

$$h_2 = h_1 - CM$$

$$h_2 = h_1 - d\tan\theta_1$$

$$h_2 = h_1 - d\left(\frac{h_1}{f_1}\right)$$

Hence from (3)

$$\theta = \frac{h_1}{f_1} + \frac{1}{f_2}\left(h_1 - \frac{dh_1}{f_1}\right) \tag{4}$$

It can also be observed that

$$\theta = \frac{h_1}{F} \tag{5}$$

Where F is the combined focal length.

On equating equations (4) and (5), we get

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

Hence combined focal length can be determined and the distance between the uprights carrying the screen (or cross – slit) and the nodal slide (which gives the position of the axis of rotation) will, therefore, give the focal length of the lens system.

PROCEDURE:

1. First the focal length f_1 and f_2 of the two given lenses are determined. For this one of the lenses is mounted on the nodal – slide such that its optical center lies on the axis of rotation of nodal slide. The source of light, screen having the cross slit and plane – mirror are mounted on the proper uprights and the heights of uprights are adjusted in such a manner that the line joining the center of each part is parallel to the bed of the bench.
2. The cross - slit is illuminated and the plane of the mirror is adjusted till blurred and not well defined then the upright carrying the nodal slides moved(In this position light diverging from the cross-slit emerges as a parallel beam of light after passing through the lens. This parallel beam of light is reflected as a parallel beam from the plane – mirror and brought to focus on the plane of the cross –slit by the lens. In other words, the screen having the cross –slit serves as the second focal plane for the parallel beam of light coming from the plane mirror.)
3. The slide is rotated slightly about the vertical axis and lateral shift of the image is observed. If there is any shift, the position of the axis of rotation with respect to the lens is slightly changed by moving the nodal slide on the upright by means of the screw provided for this purpose. The sharpness of the image is disturbed. The image is refocused by moving the upright (carrying the nodal slide) on the optical bench. Lateral shift of the image is again observed. The same process is repeated till the image of the slit is in sharp focus and does not show any lateral shift when the nodal slide is slightly rotated about its vertical axis. The distance between the plane of the cross slit and the axis of rotation now gives the focal length of the lens.
4. The lens is rotated through 180^0 and the whole process is repeated. The mean of the two distances, thus obtained, will give the exact focal length f_1 on the first lens.
5. The first lens is removed and the second lens is mounted on the nodal slide . Its focal length f_2 is determined in the same manner as described.

6. To determine the focal length of the combination, the two lenses are mounted on the nodal slide at some distance apart (the lenses are being placed equidistance and on opposite sides of the axis of rotation) By adjusting the inclination of the plane mirror and the position of the nodal slide the image of the cross slit is made to lie on the side of the slit itself. The shift in the image due to a slight rotation of the nodal slide is observed. If there is any lateral shift, with the simultaneous focusing of image a suitable position of the nodal slide is determined for which no lateral shift of the image occurs due to a slight rotation of the nodal slide now gives the focal length of the combination .
   (a) Different sets of reading are to be taken by turning the faces of the lens through 180^0 and inter –changing the position of the component lenses.
   (b) The experiment is repeated for different values of x – the distance between the lenses (say 4,6,8 cm)
   (c) The focal length of the combination is also obtained theoretically for each value of d by the formula $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$

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

It will be found that experimental and theoretically value of the focal length of the combination for given separation agree fairy well thus verifying the truth of the formula.

OBSERVATIONS:

(A) Observation for the focal length of the lenses

Lens	**Light Incident On**	**Position of the Cross –slit (a) (cm)**	**Position of the Axis of Rotation of the Nodal –slide (b) (cm)**	**Focal Length**	
				(b-a) (cm)	**Mean (cm)**
L_1	**One face**				**F_1 = ...**
	Other face				

L_2	**One face**				**F_2 =. . . . .**
	Other face				

(B) Observation for the combined focal length

S. No.	**Distance Between lenses (d) (cm)**	**Light Incident On**	**Position of Cross –slit (a) (cm)**	**Position of the axis of rotation of the Nodal slide (b) (cm)**	**Focal length of the system (F)**	
					(b - a) (cm)	**Mean (cm)**
1.		**One lens**				
		Other lens				
2.		**One lens**				
		Other lens				

CALCULATION:

(A) Focal length of the coaxially convergent system is given by

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

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

(a) For d =. . . . . cm. F = ...cm.

(b) For d =. . . . . cm. F =. . . . . .cm.

Mean F =. . . . . .cm.

(B) Location of cardinal points is determined as

(a) First principle point $L_1 H_1 = \frac{Fd}{f_2}$

(b) Second principle point $L_2 H_2 = -\frac{Fd}{f_1}$

(c) First focal point $L_1 F_1 = -F\left(1 - \frac{d}{f_2}\right)$

(d) Second focal point $L_2 F_2 = +F\left(1 - \frac{d}{f_1}\right)$

RESULTS:

From above calculations it is obvious that the experimental and theoretical values of the focal length of the system are nearly the same for each value of d separately. Hence the formula

$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ is verified and location of various cardinal point is also calculated.

PRECAUTIONS:

1. False images formed by partial reflection from the faces of the lenses should not be confused with the true image of the cross- slit.
2. While determining the focal length of a single lens, its optical centre must lie on the axis of rotation of the nodal slide. (for easy and quick setting)
3. Bench–error should also be taken into account.
4. The nodal slide should be rotated slightly about the axis of rotation.
5. In order to get a bright image of the slit the plane mirror should be placed as close to the combination as possible.