Nodal Slide

EXPERIMENT No. 28

Object : To determine the focal length of the combination of two lenses separated by a distance with the help of a nodal slide and to verify the formula :

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

where F = focal length of the combination,
f_1, f_2 = focal lengths of the given lenses,
x = separation of the two lenses.

Apparatus required : Nodal slide arrangement (optical bench, plane mirror, cross slit and a lamp) and two convex lenses.

Description of apparatus and theory :

Description : The nodal slide arrangement is shown in figure (1).

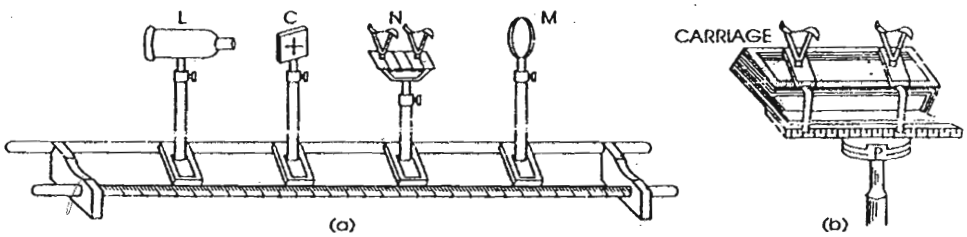

Fig. (1)

The nodal slide assembly consists of an optical bench provided with four uprights. The one upright carries a bulb placed in a metallic cover having a circular aperture, which illuminates a cross slit in the adjacent upright. The third upright carries the nodal slide. Nodal slide is essentially a horizontal metal support capable of rotating about a vertical axis; and lens or lenses can be mounted upon the support. The metallic support can be fixed or it can be moved back and forth by means of a screw so that the relative position of the two lenses can vary with respect to this upright. The support can be rotated in a horizontal plane. The fourth up-right carries a plane mirror which can be rotated about a horizontal axis perpendicular to the bed of the bench.

Theory : If parallel beam of light is incident on a converging lens system thus forming an image on 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 points.

The principle is based on the property of nodal points, *i.e.*, when a ray of light passes through one of them, its conjugate ray passes through the other and is always parallel to the incident ray. If the system is now rotated slightly about a vertical axis, the image will not be shifted from its position as shown in fig. (2).

The distance of the screen from the axis of rotation gives the principal focal length of the lens system.

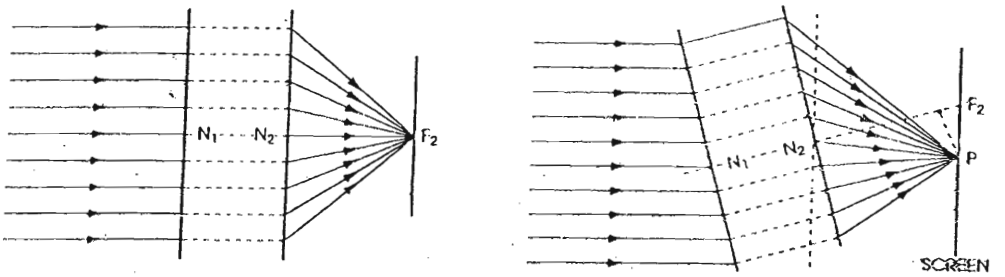

Fig. (2)

Procedure :

(i) One of the lenses L_1, the source of light, cross slit and mirror are mounted on uprights of the optical bench and the heights of uprights are adjusted in such a manner that the line joining the centres of each part is parallel to the bed of the bench.

(ii) Illuminate the cross slit and adjust the plane of the plane mirror to get the image of cross slits very near to it. The image may be blurred but the well defined image is formed by moving the upright of nodal slide away or towards the cross slits.

(In this case light from the source after passing through the cross slits emerges from the lens as a parallel beam which is reflected again as parallel beam from plane mirror and brought to a focus on the plane of cross slits).

(iii) The lens is now rotated slightly about the vertical axis which shifts the position of image either towards the left or right but no shift of the image is obtained by moving the carriage carrying the lens axially. In this situation the cross slits are in the focal plane of the lens. The distance between cross slits and lens gives the focal length of the lens.

(iv) Remove the first lens and mount the second lens on the upright. As described above, find the focal length of this lens.

(v) Mount both the convex lenses on the nodal slide arrangement and note down their positions. This gives the distance between the two lenses.

(vi) Move the upright carrying the lenses towards or away from the cross slits to obtain a well defined image. Now rotate the carriage on its upright by a few degrees and if there is a shift of the image, move the carriage on its upright by means of rack and pinion arrangement till there is no shift. Note down the positions of the uprights carrying the cross slits and nodal slide assembly on the optical bench. This distance gives the combined focal length of the two lenses.

(vii) Rotate the lens system by 180° and repeat the above procedure.

(viii) Alter this distance between two lenses and find out the combined focal lengths.

(ix) Find out the bench error between the uprights carrying cross slits and nodal assembly.

Observations :

Table for focal length of a lens :

Bench error = ... cms.

S. No.	Light incident on	Lens L_1			Mean f_1	Lens L_2			Mean f_2
		Position of cross slit (a)	Position of lens (b)	f_1 $a-b$		Position of cross slit (a)	Position of lens (b)	f_2 $a-b$	
1	one face	...	...	...		...	...		
	other face	..	...	...		...	...		
2	one face	...	...	...		...	...	...	
	other face	...	...	...	...	...	...	...	...
3	one face	...	...	...		...	...	...	
	other face	...	...	...		...	...	...	

Total for focal length of the combination :

S. No.	Light incident on	Distance between lenses	Position of cross slit (a)	Position of nodal slide upright (b)	$F = (a \sim b)$ (c)	Calculated value of F (d)	Difference ($c - d$)
1	one face	$\ldots x_1$	...	...	...	...	...
	other face		...	...	...	...	...
2	one face	$\ldots x_2$	...	...	...	...	...
	other face		...	...	...	...	...
3	one face	$\ldots x_3$	...	...	...	...	...
	other face		...	...	...	...	...

Calculation :

Calculate the combined focal length with the help of the formula

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

Result : The calculated and experimentally observed values of the focal length of the combination are very nearly equal and hence the formula

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{x}{f_1 f_2} \text{ is verified.}$$

Precuations and Sources of error :

(i) Source, slits, nodal slide arrangement and plane mirror should be rotated about a vertical axis by few degrees.

(ii) Slit should be well illuminated.

(iii) The carriage carrying the nodal slide arrangement should be rotated about a vertical axis by few degrees.

(iv) 'No image shift position' should be obtained accurately

(v) Bench error should be determined.

(vi) The mirror should be truly plane.

Theoretical error :

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

or
$$F = \frac{f_1 f_2}{f_1 + f_2 - x}$$

Taking log and differentiating

$$\frac{\delta F}{F} = \frac{\delta f_1}{f_1} + \frac{\delta f_2}{f_2} + \frac{\delta (f_1 + f_2 - x)}{(f_1 + f_2 - x)}$$

= .....

Maximum possible error = ...%.