EXPERIMENT 12

AIM

To find the focal length of a concave lens with the help of a convex lens.

APPARATUS AND MATERIAL REQUIRED

An optical bench with uprights for holding the lenses and two needles, a thin concave lens, a convex lens of focal length (~15 cm) smaller than that of the concave lens, index needle (may be a knitting needle), a metre scale and a spirit level.

PRINCIPLE

Figs. E 12.1 (a),(b),(c) and (d) illustrate the formation of image A′ B′ of an object AB by a concave lens. It is clear that the image formed by a

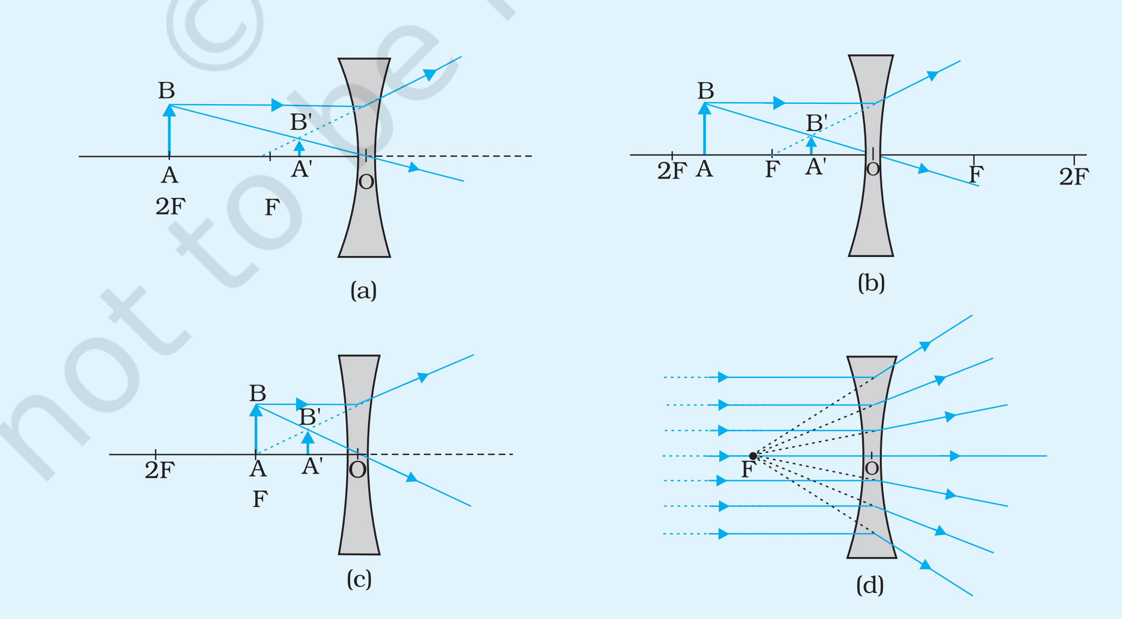

Fig. E 12.1 (a),(b),(c), (d) *The images formed by a concave lens for different object positions*

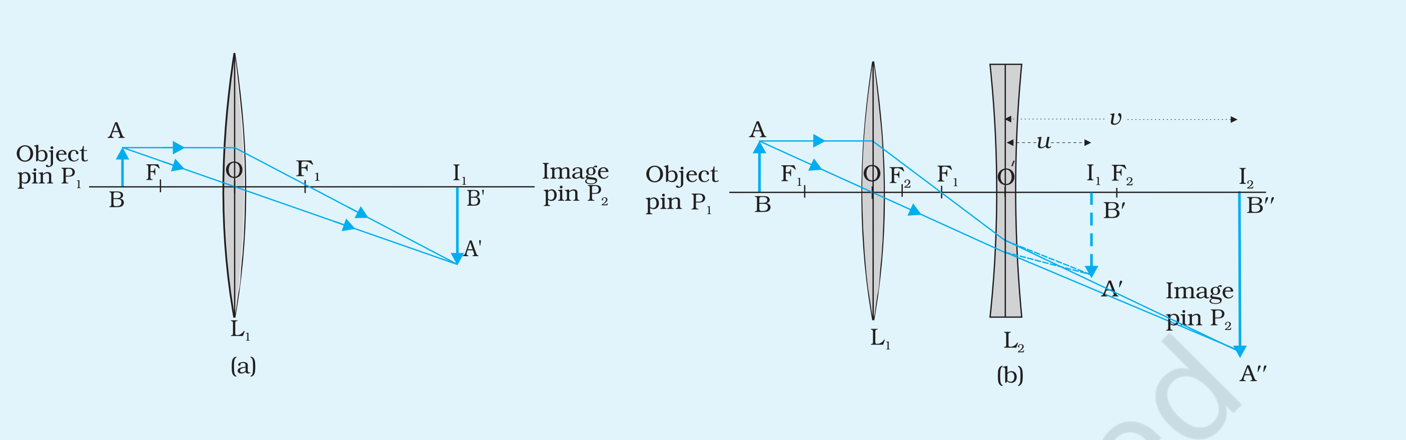

Fig. E 12.2 *Formation of image (a) by a convex lens; and (b) by a combination of convex lens and concave lens*

concave lens is always virtual and erect in these cases. Therefore, its focal length cannot be determined directly. However, it can be determined indirectly by introducing a convex lens in between the object and the concave lens and producing a real image as illustrated in Fig. E12.2.

A convex lens L_1 converges the light rays starting from the object AB to form a real and inverted image A′B′ at position I_1 [Fig. E 12.2(a)]. If a concave diverging lens L_2 is inserted between the lens L_1 and point I_1 as shown in Fig. E 12.2 (b), for concave lens L_2 image A′ B′ behaves as virtual object. A real and inverted image A″ B″ is formed at point I_2 by the diverging lens L_2. Thus, for the concave lens L_2 the distances O′ I_1 and O′ I_2 would be the distances u and v, respectively. It is important to note that the focal length of convex lens L_1 must be smaller than the focal length of the concave lens L_2. The second image A″ B″ is formed only when the distance between lens L_2 and first image A′B′ is less than the focal length of L_2.

The focal length of the concave lens L_2 can be calculated from the relation

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u} \quad \text{or} \quad f = \frac{uv}{u - v} \qquad \text{(E 12.1)}$$

Here for the concave lens both distances u and v are positive and since u will be found to be less than v, f will always be negative.

PROCEDURE

1. In case, if the focal length of the given thin convex lens is not known then rough value of its focal length (f_L) should be estimated first to ensure that its focal length is less than that of the concave lens.

2. Place the optical bench on a rigid platform and using the spirit level, make it horizontal with the help of levelling screws provided at the base of the bench.

3. Place the uprights mounted with pin P_1 (object pin), convex lens L_1, and another pin P_2 (image pin) on the optical bench. You may put a small piece of paper on image pin P_2 to differentiate it from the image of object pin P_1 [Fig. E 12.2(a)].

4. Check the collinearity of the tip of pin P_1, optical centre O of convex lens L_1, and the tip of image pin P_2 along a horizontal straight line which is parallel to the length of the optical bench. In this condition the planes of lens and both the pins would be perpendicular to the axis of the lens.

5. For the determination of the index correction, bring a mounted pin close to the concave lens L_2. Adjust the index needle (a sharp-edged knitting needle would also serve the purpose) horizontally such that its one end touches one of the curved surfaces of the lens and the other end touches the tip of the pin. Note the positions of the two uprights on the scale provided on the optical bench. The difference of the two would give the *observed length* of the index needle. The *actual length* between the tip of the pin and optical centre O′ of the lens L_2 would be length of the index needle (as measured by a scale) plus half of the thickness of the lens at its optical centre. The difference of the two lengths is the index correction.

   (If the concave lens is thin at the centre, its thickness at the centre can be ignored).

6. Separate the object pin P_1 from the convex lens by a distance slightly greater than the focal length f_L of the lens.

7. Locate its real and inverted image at point I_1 on the other side of the lens by removing the parallax between the image pin P_2 and image of the object pin P_1 [Fig. E 12.3(a)].

8. Read the positions of the uprights holding the object pin P_1, convex lens L_1, and image pin P_2 (i.e. point I_1). Record these observations in Table E 12.1.

9. From now on, do not change the position of the convex lens L_1 and the position of the object pin P_1. Insert the concave lens L_2 in between the convex lens L_1 and image pin P_2. Now the image of object pin will shift further from the convex lens L_1 to a point I_2(say). Adjust the position of the concave lens so that the point I_2 is sufficiently away from the point I_1.

10. In case the image formed by the combination of convex and concave lenses is not distinctly visible, try to see it on moving the concave lens nearer to the point I_1 and to locate the image by using a pencil

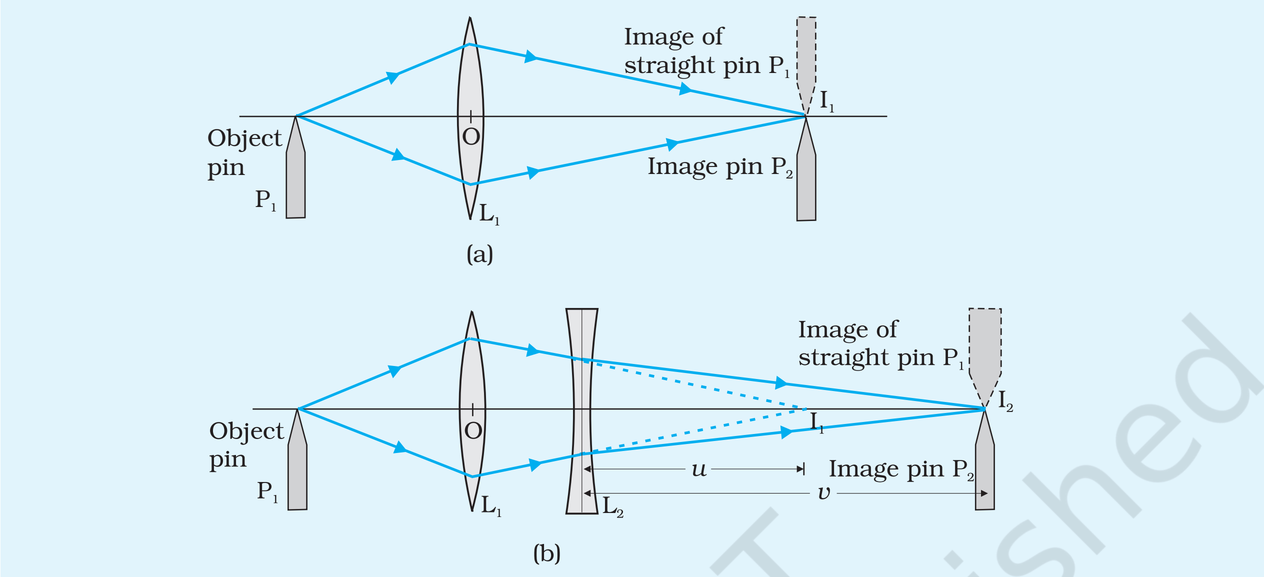

Fig. E 12.3 *Focal length of concave lens with the help of convex lens*

held in hand, and keeping the image pin P_2 at point I_1 as a guide to decide which way to shift the concave lens L_2. After having seen the clear image at point I_2 and ensured that it lies within the range of the optical bench, move image pin P_2 to locate the image (or point I_2) more accurately using the method of parallax [Fig. E 12.3(b)]. Since the image forming at I_2 is quite enlarged, it can be blurred.

11. Note the position of uprights holding the concave lens and image pin P_2, *i.e.*, point I_2. Note the readings in the Observation Table.

12. Change the position of upright holding the object pin P_1 and repeat the steps 6 to 11. Take five sets of observations.

OBSERVATIONS

1. Focal length of the convex lens, f_L = ... cm

2. Length of the index needle as measured by the scale, s = ... cm

3. Thickness of the thin concave lens (given) at its optical centre, t = ... cm

4. Actual length between the optical centre O of the lens and tip of the pin, $l = s + t/2$ = ... cm

5. Observed length of the index needle, l'

   = Distance between the pole of the lens and tip of the pin

   = Position of lens upright - position of pin upright on the scale

   = ... cm

Table E 12.1: Determination of *u*, *v*, and *f* of concave lens

Sl. No.	Position of										
	Object pin upright P_1, *a* (cm)	Convex lens L_1 upright, *b* (cm)	Image formed by L_1, point I_1, *c* (cm)	Concave lens L_2 upright, *d* (cm)	Image formed by L_1 and L_2, point I_2, *g* (cm)	Observed *u* = *c* – *d* (cm)	Observed *v* = *g* – *d* (cm)	Corrected *u* = Observed *u* + *e* (cm)	Corrected *v* = Observed *v* + *e* (cm)	$f = uv/(u - v)$ (cm)	Δf (cm)
1											
2											
--											
5											
									Mean		

6. Index correction, $e = l - l' = \ldots$ cm

CALCULATIONS

Find the focal length of the concave lens using the formula $f = \dfrac{uv}{u - v}$

Error

$$\frac{1}{f} = \frac{1}{v} - \frac{1}{u}$$

$$\frac{\Delta f}{f^2} = \frac{\Delta v}{v^2} + \frac{\Delta u}{u^2}$$

$$\Delta f = f^2 \left[\frac{\Delta v}{v^2} + \frac{\Delta u}{u^2} \right]$$

where Δu, Δv represent least counts of the measuring scale. Values of *u*, *v*, *f* are to be taken from the Observation Table. Maximum of the five values of the error Δf is to be reported with the result as error.

RESULT

The focal length of the given concave lens is ($f \pm \Delta f$) = ... ± ...cm.

Here f is mean value of the focal length.

PRECAUTIONS

1. The concave lens must be placed near the convex lens. In fact, the second image I_2 is formed only when the distance between concave lens L_2 and first image I_1 (which acts as virtual object for the concave lens) is less than the focal length of the concave lens.
2. Since the image formed at I_2 is quite enlarged, it can be blurred. Therefore, it would be preferable to use a thin and sharp object pin and shine it with light using a lighted electric bulb.
3. The convex lens and the pin P_1 must not be disturbed during the second part of the experiment.
4. A diminished, real and inverted image of the image pin P_2 might also be formed by the light rays reflecting from the concave surface of the lens L_2. It should not be confused with the bold and bright image formed by the combination of convex and concave lenses.
5. Index correction/ bench correction for u and v should be made.

SOURCES OF ERROR

1. If tip of object pin and optical centre of the lens are not aligned properly (if not brought at the same horizontal level), image tip and image of object pin tip will not touch each other. There may be some gap between the two or there could be overlap between the two. In such situations, there can be error in removing parallax and it will lead to errors in the result.
2. For greater accuracy we should use sharply pointed object pin.

DISCUSSION

1. As concave lens diverges the rays, the image formed by a concave lens alone will not be real and cannot be taken on a screen. To converge these diverging rays to form a real image, convex lens is used.
2. Diverging rays from concave lens can be made to fall normally on a concave mirror to get the real image formed at the point where object is placed. Hence, the focal length of the concave lens can be found by using a concave mirror also.

3. Since the image I_2 is quite enlarged, it can get blurred by chromatic aberration of the two lenses. Thus it is better to put a screen behind object pin P_1 and thus do the entire experiment with one colour of light instead of with white light. For the same reason, pin P_1 should be quite thin and sharp compared to pin P_2.

SELF ASSESSMENT

1. In this experimental setup the combination of concave lens and convex lens separated by a distance *d* behaves as a single lens of focal length *F*. Check the relation $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{d}{f_1 f_2}$ for any one of the observations.

2. Calculate *f* by interchanging the value of *u* and *v* and compare it with the experimentally determined value of *f*.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Plot a graph of *uv* against *u*–*v* with *uv* on y-axis and *u*–*v* on x-axis. Determine *f* from the slope of the graph.

2. Repeat the experiment by using concave and convex lenses of different focal lengths, compare and analyse the results.