AIM

To find the focal length of a convex mirror using a convex lens.

APPARATUS AND MATERIAL REQUIRED

An optical bench with uprights for holding lens, mirror and two needles, two needles (pins), a thin convex lens, a convex mirror, index needle (may be a knitting needle or a pencil sharply pointed at both ends), a metre scale and a spirit level.

PRINCIPLE

Fig. E 11.1 illustrates the formation of image of an object AB by a convex mirror MM′ (having a small aperture) in two different situations. The image formed by a convex mirror is virtual and erect. Therefore, its focal length cannot be determined directly. However, it can be determined by introducing a convex lens in between the object and the convex mirror (Fig. E 11.2).
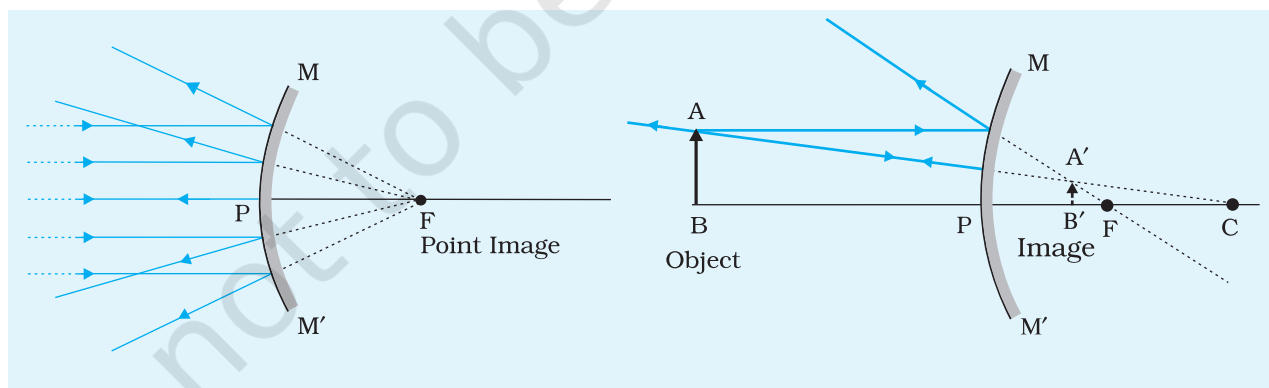

Fig. E 11.1(a) *Object is at infinity. A highly diminished and point image is located at the focus behind the convex mirror*

Fig. E 11.1(b) *Object is in front of the mirror. A diminished virtual image is produced between the pole and focus behind the mirror*

An object AB is placed at point P′ in front of a thin convex lens such that its real, inverted and magnified image A′B′ is formed at position

C on the other side of the lens [Fig. E 11.2(b)]. Now a convex mirror is introduced between the convex lens and point C and so adjusted that the real and inverted image A′B′ coincides with the object AB at point P′ [Fig. E 11.2 (a)]. This is possible if the light rays starting from the tip of the object, after passing through the lens, fall normally on the reflecting surface of the convex mirror and retrace their path. Any normal ray (perpendicular) to a spherical surface has to be along the radius of that sphere so that point C must be the centre of curvature of the convex mirror. Therefore, the distance P C is the radius of curvature R and half of it would be the focal length of the convex mirror. That is,
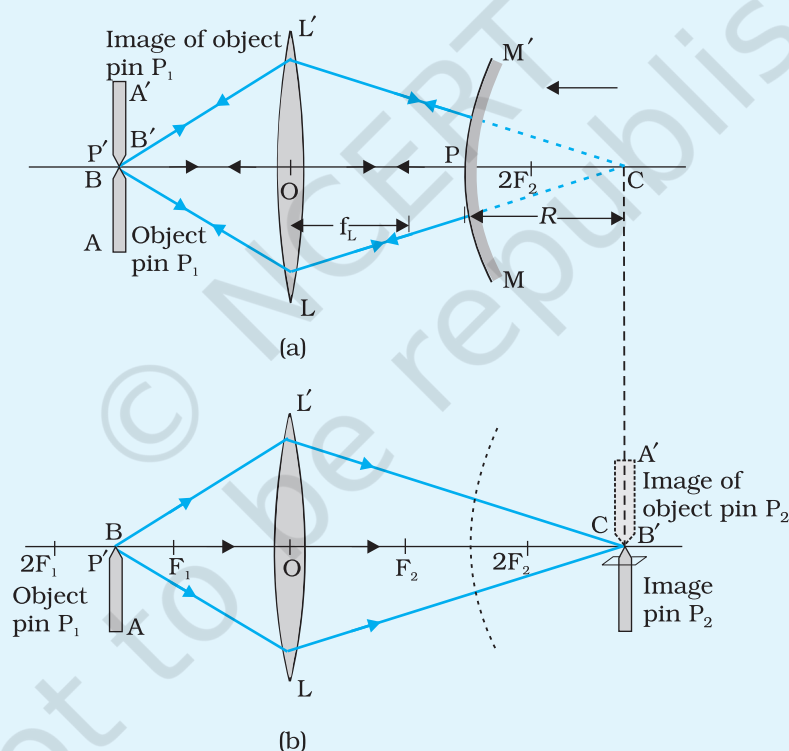
$$f = \frac{PC}{2} = \frac{R}{2}$$

Fig. E 11.2 *Image formed by (a) convex mirror and convex lens-image A′ B′ coincides with the object A B at P′ (b) convex lens- image is inverted and magnified*

PROCEDURE

1. In case, if the focal length of the given thin convex lens is not known then approximate value of its focal length should be estimated first.

2. Place the optical bench on a rigid table or on a platform. 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 LL′, and convex mirror MM′ on the horizontal optical bench [Fig. E11.2(a)].

4. Check that the lens, mirror, and pin P_1 are vertically placed on the optical bench. Also verify that the tip of the pin, optical centre O of the convex lens LL′, and pole P′ of the convex miror MM′ lie on the same horizontal straight line, parallel to the optical bench.

5. Determine the index correction between upright holding of the convex mirror and image pin respectively, using an index needle.

6. Place the object pin P_1 from the convex lens LL′ at a distance slightly greater than the focal length of the lens.

7. Adjust the position of the convex mirror MM′ till the light rays reflected back from the mirror pass through the lens and form a real and inverted image coinciding with the object pin P_1, as shown in Fig.E 11.2 (a). This occurs when the rays starting from the tip of pin P_1, after passing through the lens strike the mirror normally and are reflected back along their original paths. Remove the parallax between the image and object pins.

8. Read the position of uprights holding the object pin P_1, convex lens LL′, and convex mirror MM′ and record the observations in the observation table.

9. Remove the convex mirror from its upright and fix image pin P_2 on it. Adjust the height of pin such that the tip of it also lies on the principal axis of the lens. That is, the tips of the pins P_1 and P_2 and the optical centre O of the convex lens, all lie on a straight horizontal line parallel to the length of the optical bench.

10. You may put a small piece of paper on image pin P_2 to differentiate it from the object pin P_1.

11. Using the method of parallax and without changing the position of lens LL′ and object pin P_1, adjust the position of image pin P_2 on the other side of the lens so that it coincides with the real and inverted image of the object pin P_1 formed by the convex lens [Fig. E 11.2(b)]. Note the position of the image pin.

12. Repeat the experiment by changing the separation between the pin P_1 and lens L L′ and the mirror MM′. In this manner, take five sets of observations.

OBSERVATIONS

1. Focal length of the convex lens, f (estimated/given) = ... cm

2. Actual length of the index needle, l = ... cm

3. Observed length of the index needle l'

   = Position of mirror upright – position of pin upright on the scale
   = ... cm

4. Index correction, e = Actual length – observed length $(l - l') =$ ... cm

Table E 11.1: Determination of radius of curvature of convex mirror, R

Sl. No.	Upright position of				Observed $R' = c - d$ (cm)	Corrected R Observed $R' + e$ (cm)	Focal length f (cm)	Δf (cm)
	Object pin P_1 a (cm)	Convex lens LL' b (cm)	Convex mirror MM' c (cm)	Image pin P_2 d (cm)				
1								
2								
--								
5								

Mean

CALCULATIONS

Calculate the mean value of radius of curvature of the convex mirror, R, and determine its focal length using the following relation

$$f = \frac{R}{2} = ... \text{ cm}$$

Error

$$f = \frac{R' + l}{2} = \frac{(c - d) + (l - l')}{2}$$

$$\frac{\Delta f}{f} = \frac{\Delta c}{c} + \frac{\Delta d}{d} + \frac{\Delta l}{l} + \frac{\Delta l'}{l'}$$

when Δc, Δd, Δl and $\Delta l'$ are the least counts of the measuring instruments. Maximum of the five values of Δf is to be reported with the result as the experimental error.

RESULT

The focal length of the given convex mirror is $(f \pm \Delta f)$ ... $\pm$ ... cm.

Here f is mean value of the focal length.

PRECAUTIONS

1. The uprights supporting the pins, lens and mirror must be rigid and mounted vertically.
2. The apertures of the given convex lens and convex mirror should be small, otherwise the image formed will be distorted.
3. Eye should be placed at a distance of about 25 cm or more from the image pin.
4. Optical bench should be horizontal. The tips of pins, centre of convex lens and pole of the mirror should be at the same horizontal level.

SOURCES OF ERROR

1. The tip of the inverted image of the object pin should just touch the tip of the image pin and must not overlap. This should be ensured while removing the parallax.
2. Personal eye defects may make removal of parallax tedious.
3. The convex mirror should preferably be front-coated. Otherwise multiple reflections may take place.

DISCUSSION

It may not be possible to perform this experiment with just any convex lens. The focal length of the lens used in this experiment should neither be too small nor too large. Why?

SELF ASSESSMENT

1. If focal length of the concave mirror is determined, by using convex lenses of different focal lengths, do you expect any change in the result? If yes, what type of change? If not, why not?

2. How will the result change if a convex lens of different refractive indices were used?

3. If the convex lens selected for the experiment has focal length less than that of the convex mirror, how would this selection limit the experiment?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Repeat the experiment by using convex lenses of different focal lengths. Compare and analyse the results.

2. Repeat the experiment by using convex mirrors of different focal lengths with the help of the same convex lens. Discuss the results.