EXPERIMENT 10

OBJECTIVE

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

APPARATUS

An optical bench with four uprights (two fixed uprights in middle, two outer uprights with lateral movement), convex lens (20 cm focal length), convex mirror, a lens holder, a mirror holder, two optical needles, (one thin, one thick) a knitting needle, and a half metre scale.

RAY DIAGRAM (*Fig. 7.09*)

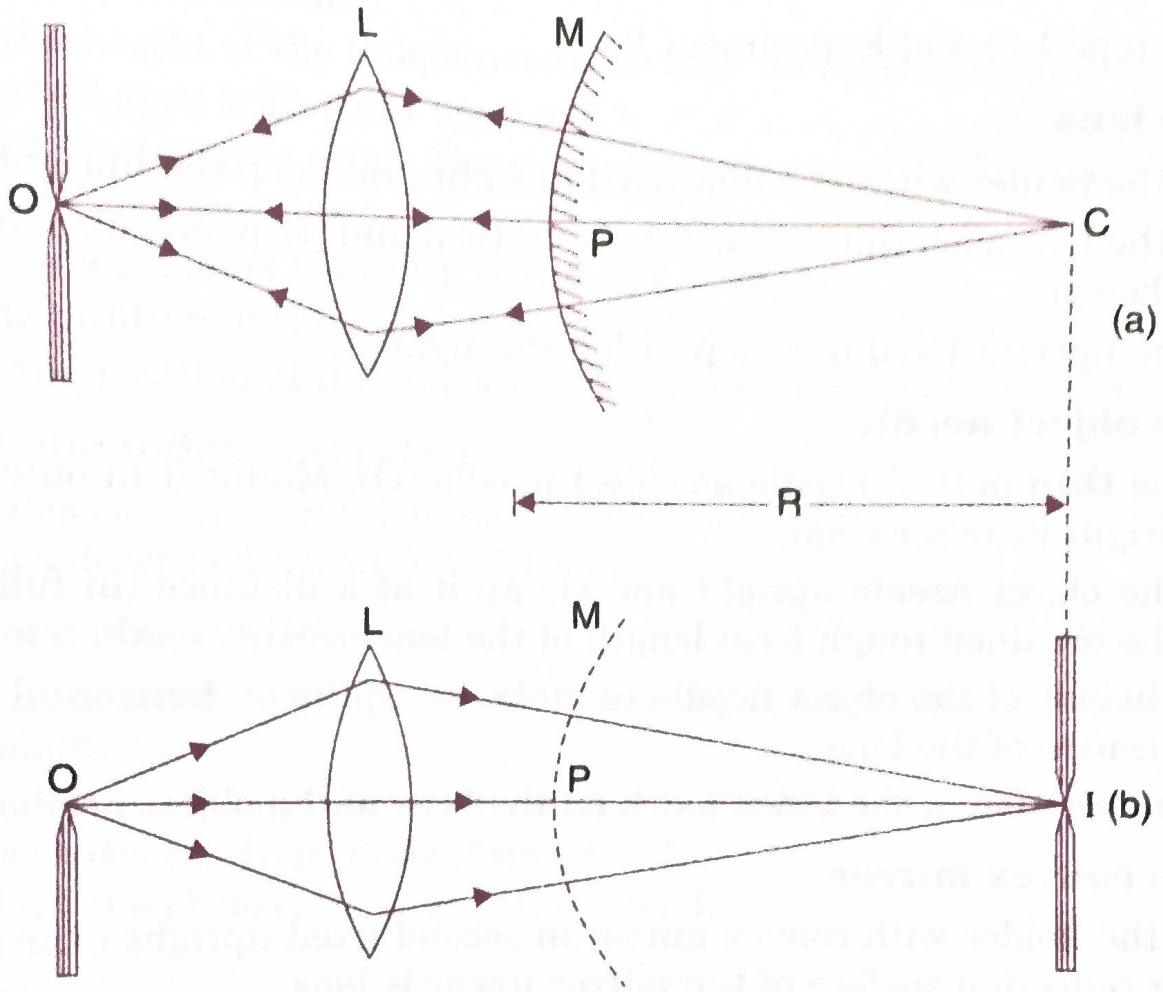

Fig. 7.09. Focal length of convex mirror.

A Short Description about the Arrangement

As a convex mirror always forms a virtual image, its focal length can not be found directly as for a concave mirror. For this purpose, **indirect** method is used, as described below.

An auxiliary convex lens L is introduced between the convex mirror M and object needle O as shown in Fig. 7.09 (*a*). Keeping the object needle at distance about 1.5 times rough focal length of convex lens, the position of convex mirror behind convex lens is so adjusted that a real and inverted image of object needle O, is formed at O itself. Under such condition, the light rays are incident normally over the convex mirror to retrace their path. In the absence of convex mirror, these rays would have met at centre of curvature C of the convex mirror. The distance PC gives the radius of curvature R of the mirror.

To locate the position of C, convex mirror is removed (without disturbing the object needle O and convex lens L). An image needle I is put behind the convex lens and moved to a position

at which there is no parallax between tip of inverted image of O needle and tip of I needle. Position of image needle I gives position of centre of curvature C of the mirror M. [Fig. 7.09 (*b*)]

Then, $\text{PC} = \text{PI} = R$ and $f = \frac{R}{2} = \frac{\text{PI}}{2}$

THEORY (*Formula used*)

Focal length of a convex mirror $f = \frac{R}{2}$

where R = radius of curvature of the mirror.

PROCEDURE (*Stepwise*)

To determine rough focal length of convex lens

1. Follow steps 1 to 4 of Experiment 9.

To set the lens

2. Clamp the holder with lens in a fixed upright and keep the upright at 50 cm mark.
3. Adjust the lens such that its surface is vertical and perpendicular to the length of the optical bench.
4. Keep the upright fixed in this position throughout.

To set the object needle

5. Take the **thin** optical needle as object needle (O). Mount it in outer laterally moveable upright near zero end.
6. Move the object needle upright and clamp it at a distance (in full cms) nearly 1.5 times the obtained rough focal length of the lens.
7. Adjust height of the object needle to make its tip lie on horizontal line through the optical centre of the lens.
8. Note the position of the index mark on the base of the object needle upright.

To set the convex mirror

9. Clamp the holder with convex mirror in second fixed upright near the lens upright, keeping reflecting surface of the mirror towards lens.
10. Adjust the height of the mirror to make its pole lie on horizontal line through the optical centre of the lens.
11. Make the mirror surface vertical and perpendicular to the length of the optical bench (the principal axes of mirror and lens must coincide.)
12. Move towards zero end of the optical bench (where object needle is mounted).
13. Closing left eye, keep open right eye about 30 cm away from the tip of the object needle.
14. See the inverted image of the object needle (formed by reflection from the convex mirror).
15. Keep the eye in a position at which the tips of the inverted image and the object needle are seen simultaneously.

16. Adjust the height of the needle so that the two tips are seen in one line with right open eye.
17. Move the eye towards right. The tips will get separated. The tips have parallax.
18. Move the convex mirror back and forth till tip to tip parallax is removed [Read Art. 7.08 (*b*)].
19. Note the position of the index mark on the base of the convex mirror upright.

To set the image needle

20. Remove the convex mirror, keeping upright in its position.
21. With left eye closed, see with the right open eye from the other end of the optical bench. An inverted and enlarged image of the object needle will be seen. Tip of the image must lie in the middle of the lens.
22. Mount the **thick** optical needle (image needle) in the fourth upright near the other end of the optical bench.
23. Adjust the height of the image needle so that its tip is seen in line with the tip of the image when seen with right open eye.
24. Move the eye towards right. The tips will get separated. The image tip and the image needle tip have parallax.
25. Remove the parallax tip to tip [Read Art. 7.08 (*b*)].
26. Note the position of the index mark on base of the image needle upright.
27. Record the position of the index marks in the table against observation 2.

To determine index correction

28. Find index correction for distance between pole of convex mirror and tip of the image needle as described [Read Art. 7.10 (*c*)].

To get more observations

29. Move object needle upright towards lens by 2 cm to get observation 1. Repeat the experiment.
30. Move object needle upright away from lens (from position of observation 2) by 2 cm to get observation 3. Repeat the experiment.
31. Record all the observations as given ahead.

OBSERVATIONS

Rough focal length of the convex lens = ... cm

Actual length of the knitting needle, x = ... cm

Observed distance between image needle I and back of the convex mirror

y = ... cm

$= (x - y)$

$\therefore$ Index correction = ... cm.

1. Table for focal length of convex mirror

Serial No. of Obs. (1)	*Position of*		*Radius of curvature (R)*		*Focal length* $f = \frac{R}{2}$ (cm) (4)
	Convex mirror P (cm) (2a)	*Image needle I (cm)* (2b)	*Observed PI (cm)* (3a)	*Corrected PI (cm)* (3b)	
1.					
2.					
3.					

CALCULATIONS

1. Write observed PI in column 3*a* and corrected PI in column 3*b*.
2. Divide corrected PI by 2 and write in column 4.
3. Find mean of values of *f* recorded in column 4.

RESULT

The focal length of the given convex mirror = ... cm.

PRECAUTIONS (*to be taken*)

1. Principal axis of the lens should be **horizontal** and **parallel** to the central line of the **optical bench.**
2. All the uprights should be **vertical.**
3. The tip of the needle, centre of the mirror and centre of the lens should be at the **same height.**
4. While removing the parallax, the eye should be kept at a **minimum distance** of 30 cm from the needle.
5. **Tip to tip parallax** should be removed.
6. **Index correction** should be applied between the image needle I and back surface of the convex mirror.
*7. The convex mirror should be placed **close** to the convex lens.
8. For one set of observation, when the parallax has been removed for convex lens alone, the positions of the lens and needle O uprights should **not be changed.**

SOURCES OF ERROR

1. Same as in Experiment 9.
2. Focal length of lens may not be small.

VIVA VOCE

Q. 1. Define a mirror ?

Ans. It is a fine polished surface which reflects most of the light that is incident on it.

Q. 2. Describe different types of mirrors ?

Ans. There are two types of mirrors : (*i*) plane mirrors (*ii*) spherical mirrors.

Q. 3. Define a spherical mirror.

Ans. Read Art. 7.01 (*a*).

Q. 4. Give types of a spherical mirror.

Ans. Read Art. 7.01 (*b*).

Q. 5. Define different terms associated with spherical mirrors.

Ans. Read Art. 7.02 (1–8).

Q. 6. Mention three special rays.

Ans. Read Art. 7.03.

Q. 7. Define sign convention.

Ans. Read Art. 7.04 (*a*).

Q. 8. Give rules of sign convention.

Ans. Read Art. 7.04 (*b*).

Q. 9. Give facts obtained from sign convention.

Ans. Read Art. 7.04 (*c*).

Q. 10. Define and give mirror formula.

Ans. Read Art. 7.05.

Q. 11. Describe various assumptions made in derivation of mirror formula.

Ans. Read Art. 7.06.

Q. 12. Define image, real image and virtual image.

Ans. Read Art. 7.07 (*a*), (*b*) and (*c*).

Q. 13. Give distinction between real and virtual image.

Ans. Read Art. 7.07 (*d*).

Q. 14. Define parallax. How is it removed ?

Ans. Read Art. 7.08 (*a*) and (*b*).

Q. 15. Define index correction.

Ans. Read Art. 7.10 (*b*).

Q. 16. Define and explain spherical aberration.

Ans. Read Art. 7.12 (*a*) and (*b*).

Q. 17. Why is a mirror silvered at the back surface ?

Ans. To avoid spoiling of mirror in rough handling.

Q. 18. Is silvering done by depositing silver coating or some other material ?

Ans. In cheap mirrors silvering is done by deposition of mercuric oxide and in good quality mirrors silvering is done by deposition of silver nitrate.

Q. 19. What is the relation between focal length and radius of curvature of a spherical mirror ?

Ans. Focal length $(f) = \dfrac{\text{Radius of curvature } (R)}{2}$ or $R = 2f$.

Q. 20. What is the radius of curvature of a plane mirror ?

Ans. Infinite.

Q. 21. Is mirror formula applicable for a plane mirror ?

Ans. Yes, it is applicable. It is proved below :

From mirror formula, $\dfrac{1}{u} + \dfrac{1}{v} = \dfrac{1}{f}$

For a plane mirror, $R = \infty$, hence $f = \infty$ and $\dfrac{1}{f} = 0$

Mirror formula becomes, $\dfrac{1}{u} + \dfrac{1}{v} = 0$ or $\dfrac{1}{u} = -\dfrac{1}{v}$ or $v = -u$

It means that the image is virtual (v is positive, as u is negative). It is as much behind the mirror as the object is infront of it. Its magnification is 1 $\left(\because \dfrac{v}{u} = 1\right)$.

Q. 22. Can we find the rough focal length of a convex mirror ? If not, why ?

Ans. No, we cannot find the rough focal length of convex mirror. It is so because the image formed by a convex mirror is always virtual and cannot be obtained on a screen.

Q. 23. What type of mirror is used for dressing table and why ?

Ans. A plane mirror is used for dressing table because it gives a virtual image of the *same size* as the object placed in front of it.

Q. 24. What type of mirror is used as shaving glass ?

Ans. Concave mirror of large focal length is often used as shaving glass. Because when a concave mirror is held near the face, *i.e.* face lies between its pole and focus, an erect and enlarged image of the object is formed. An enlarged image of the face helps in having a better shave.

Q. 25. Why a convex mirror is used as a driving mirror in automobiles ?

Ans. A convex mirror forms virtual, erect and diminished image for all positions of an object. As the image is diminished in size, a wider field of view behind the automobile is covered. The two characteristics of the image formed by convex mirror *viz*. erect and wider field of view help the driver in driving the automobile with ease.

Q. 26. Which mirror is used by a surgeon and why ?

Ans. A concave mirror of small aperture is used by a surgeon to throw a narrow and sharp beam of light into the eye, nose, ear and throat for medical check up.

Q. 27. What types of mirror are used in search lights and in head lights of the vehicles ?

Ans. Parabolic mirrors are used as reflectors in head lights of the vehicles. As the search lights are meant for throwing light to very large distances. If a source of light is placed

at the principal focus of the parabolic mirror, after reflection from the mirror a beam of light can be obtained which will be parallel to the principal axis of the mirror. Thus parabolic mirrors are used in search lights.

Q. 28. Why we do not use a concave mirror for search light ?

Ans. Large aperture of concave mirror will cause spherical aberration. Rays from sources of light, kept at focus, will not be quite parallel after reflection from mirror.

Q. 29. How will you distinguish between a plane, a concave and a convex mirror, without touching them ?

Ans. We see our face in the mirror from a close distance. In all cases virtual images will be formed. Judge the magnification of the image.

If the magnification is one, mirror is plane.

If the magnification is more than one (enlarged image), mirror is concave.

If the magnification is less than one (diminished image), mirror is convex.

Q. 30. What is the sign of focal length of a concave and convex mirrors ?

Ans. The focal length of concave mirror is taken negative, while focal length of convex mirror is taken positive.

f = + ve for convex mirror

f = – ve for concave mirror.