ACTIVITY 12

AIM

To observe diffraction of light due to a thin slit.

APPARATUS AND MATERIAL REQUIRED

Two razor blades, one adhesive tape/cello-tape, source of light (electric bulb/ laser pencil), a piece of black paper, two glass plats.

PRINCIPLE

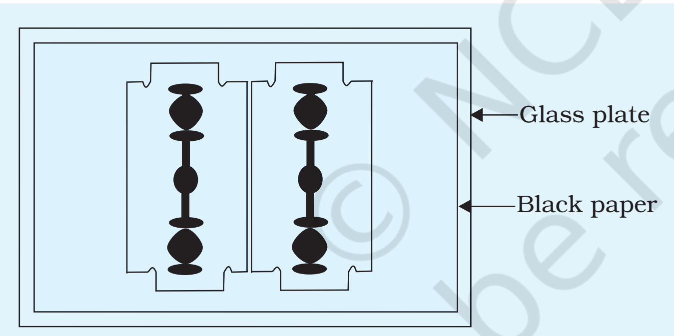


Fig. A 12.1 *A fine slit made by using two razor blades, one glass plats and a piece of black paper.*

When a beam of light passes through a fine opening (aperture) or around a sharp obstacle, it bends around corners of the obstacle/aperture. The light beam spreads and penetrates into the geometrical shadow of the obstacle. This phenomenon of bending of light around fine openings/obstacles is called diffraction and is one of the evidences in favour of wave nature of light. It arises because of the interference of light waves from different points of the same wave front. Two razor blades with their sharp edges held parallel, quite close to each other (separation being of the order of wavelength of light λ) form a fine single slit (Fig. A 12.1). The diffraction pattern due to a single slit consists of a central bright band, surrounded on both sides by coloured bands (with electric bulb) and alternate dark and bright bands (with laser pencil) of decreasing intensity and fringe width.

PROCEDURE

1. Make a fine, single slit using razor blades. For this purpose, take a glass plate and fix a black paper on top of it. Cut out a narrow slit in the central part of the black paper. Place two razor blades, side by side, quite close to each other over this slit as shown in Fig. A 12.1.

2. Place a glowing clear electric lamp preferably with a straight filament (or a laser pencil) at sufficient distance (about 4 to 8m) behind the fine slit between the two sharp edges of the razor blades. Observe the lamp through the slit. What do you find?

3. Alternatively, place the slit about 0.5m from the wall and the source of light at a distance of about 15-20 cm behind the slit. Observe the light falling on the wall.

4. Repeat the observations of steps 2 and 3 with a laser pencil. Note the changes you observe.

RESULT

Light waves incident on very fine apertures (openings) bend arround corners and exhibit phenomenon of diffraction.

DISCUSSION

1. The sharpness of diffraction fringes depends mainly on the extreme fineness of the slit, made using razor blades, keeping them quite close to each other.

2. Monochromatic light from a laser pencil is preferred over ordinary electric bulb for obtaining better effect on the screen.

   With ordinary light (an electric bulb) not many fringes are observed clearly, while with a monochromatic source (laser pencil) a large number of distinct bright and dark fringes are observed for a reasonable width of the slit.

SELF ASSESSMENT

1. Hold two razor blades side by side so that nearer sharp edges are parallel and quite close to each other. The two edges are often not parallel to each other when held like this. Do you expect the bands to become wider and/or closely spaced at a point/part of the slit where the separation of the edges is less? Do you find bands having some colours? Interpret your observations.

   [**Hint:** The position of all the bands, except the central band, depends on wavelength and they will show some colours. Use of a filter for red or blue will make the bands/fringes clearer. You can easily observe wider bands/fringes by using a red filter compared to that by using a blue filter.

2. The diffraction pattern is observed for slit widths of the order of wavelength λ of light used. Observe what happens when the slit width is few times λ. Interpret the reason.

ACTIVITY 13

AIM

To study the nature and size of the image formed by (i) a convex lens (ii) a concave mirror on a screen by using a candle and a screen (for different distances of the candle from the lens/mirror).

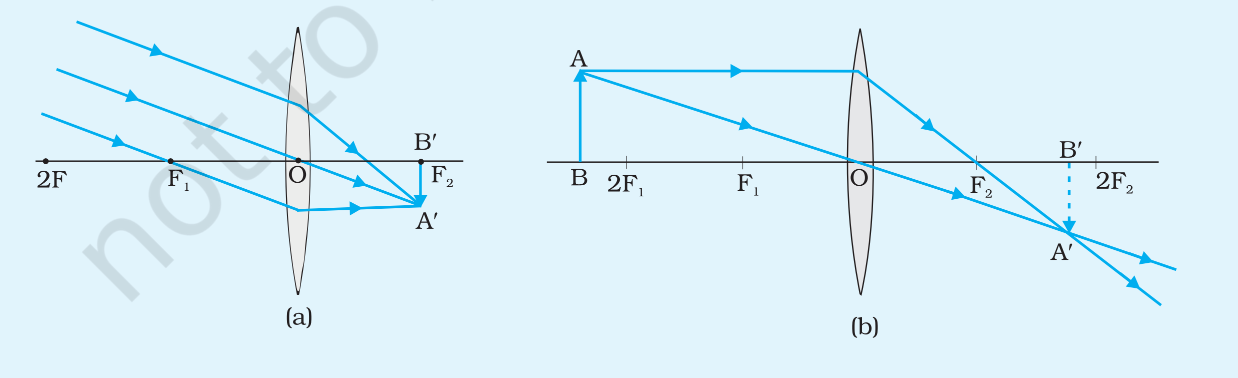
(i) To study nature and the size of the image formed by a convex lens. (for different distances of the candle from the lens)

APPARATUS AND MATERIAL REQUIRED

A candle, match box, a small candle-stand, a convex lens of small focal length and known thickness, a screen with a stand, metre scale.

PRINCIPLE

The position, nature and size of the image of an object formed by a thin convex lens varies with the change in the position of the object as illustrated in Fig. A 13 (i).1(a) to A 13 (i).1(f) for some specific positions. It is assumed that both the spherical surfaces of the lens have same radi of curvature.



(a) Object is at infinity, i.e., $u = \infty$. A real, inverted and highly diminished image is formed at the second principal focus, F_2 on the other side of the lens, i.e. $v = f$, (i) when incident rays of light is parallel to the principal axis; and (ii) when incident rays of light are not parallel to

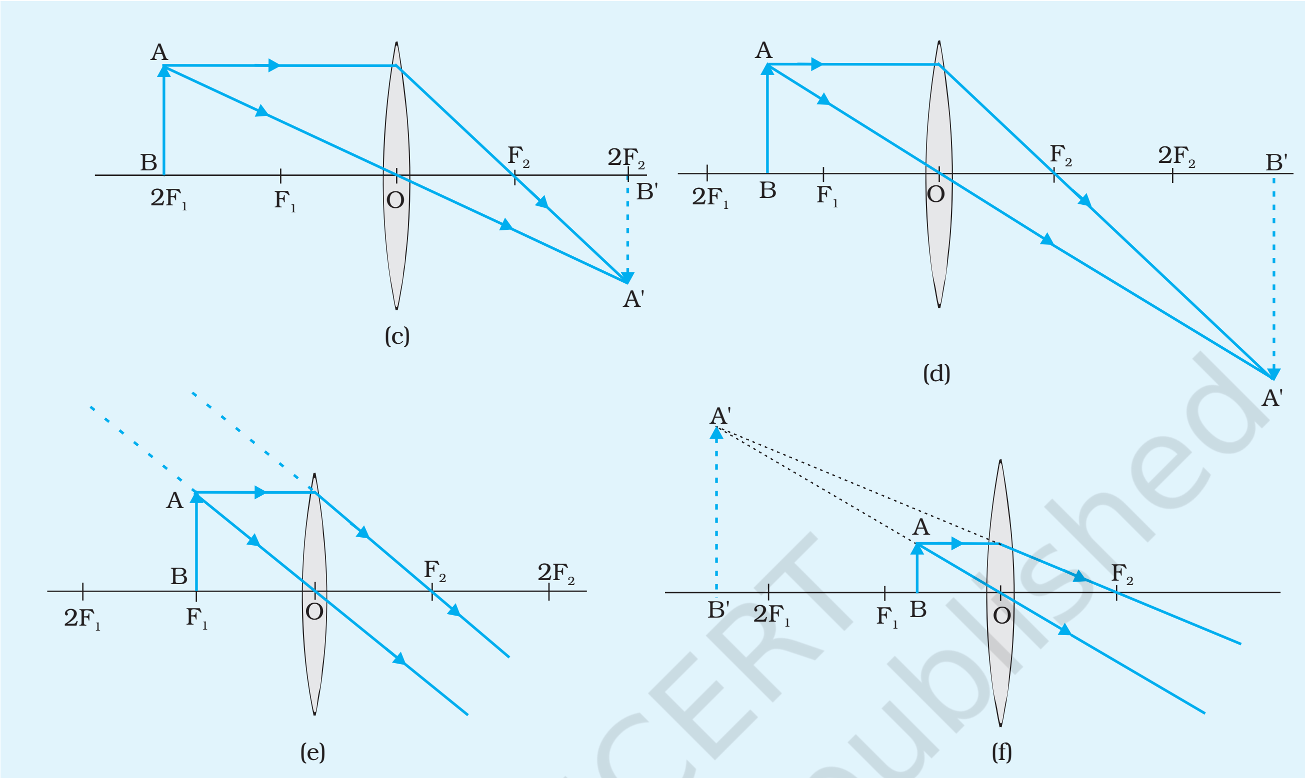


Fig. *A 13 (i).* 1 (a), (b), (c), (d), (e), (f) *The position, size and nature of the image A′ B′ formed by a thin convex lens LL′ for different positions of the object AB.*

the principal axis, the image is formed on the principal axis and focal plane respectively.

(b) Object is in between infinity and 2F$_1$, i.e., $\infty > u > 2f$. A real, inverted and diminished image lies in between second principal focus F$_2$ and 2F$_2$ on the other side of the lens, i.e., $2f > v > f$.

(c) Object is at 2F$_1$, i.e., $u = 2f$. A real and inverted image is also formed at 2F$_2$ on the other side of the lens, i.e., $v = 2f$. The size of the image is equal to the size of object.

(d) Object is in between 2F$_1$ and first principal focus F$_1$, *i.e.*, $2f > u > f$. A real, inverted and enlarged image is formed in between 2F$_2$ and infinity on the other side of the lens, i.e., $2f < v < \infty$.

(e) Object is at the first principal focus, i.e., $u = f$. A highly enlarged, real and inverted image is formed at infinity on the other side of the lens, i.e, $v = \infty$.

(f) Object is in between the principal focus and the optical centre O of the lens, i.e., $f > u > 0$. An enlarged, virtual and erect image is formed on the same side of the object.

PROCEDURE

1. Obtain an approximate value of the focal length of the convex lens by focussing the image of a distant object. It can be found by obtaining a sharp image of Sun or tree on a plain wall, on the other side of the lens and measuring the distance between the lens and the wall with a scale. This distance is approximate value of the focal length, *f* of the convex lens.

Note: *Do not look at the Sun through the lens to see its image as it will hurt your eyes.*

2. Fix a metre scale along the edge (lengthwise) of the table with a clamp or a cellotape.

3. Fix lens LL′ in a lens stand and place it approximately in the middle of the metre scale such that its principal axis is horizontal and parallel to the metre scale. In this position the lens would lie in a plane perpendicular to the table.

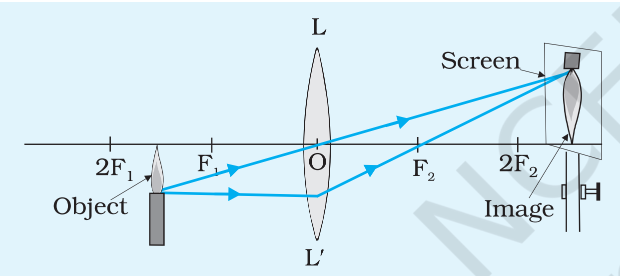


***Fig. A 13 (i). 2** Real images of a lighted candle formed by a thin convex lens.*

4. Mount a lighted candle vertically on a small candlestand. Place this candlestand on the left hand side of the lens. Adjust the upright such that the tip of the lighted candle lies on the principal axis of the lens. In this situation, the height of the tip of the flame of lighted candle becomes equal to the height of the optical centre of the lens.

5. Shift the candlestand (from left side of the lens) to a point slightly away from $2F_1$ (i.e., to a distance slightly more than $2f$ from the point O, where f is the focal length of the lens as determined in step 1). According to Fig. A13 (i).1(b), the image of candle will be formed at a position closer to the second principal focus F_2 on the right hand side of the lens.

6. Place a vertically mounted screen on the right hand side of the lens. Adjust its height such that most of its portion lies above the principal axis of the lens (Fig. A 13 (i)2).

7. Shift the position of the screen near to the second principal focus F_2 on the metre scale functioning as an optical bench.

8. Make final adjustments to get a sharp image of the lighted candle on the screen. Note the nature of the image.

9. Measure the height of the flame of the lighted candle using a small plane mirror strip with a graph paper strip pasted on it. Also

measure the height of the image of the flame being formed on the screen. For this, fix a small graph paper on the screen. Alternatively, fix a white paper on the screen and mark the positions of the top and bottom of the image and determine the height of the image using a metre scale.

10. Shift the lighted candle towards the lens by a small distance (say by 5 cm or 3 cm). Repeat steps (8) and (9) and record observations. In this manner take at least six sets of observations.

OBSERVATIONS

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

Table A 13 (i) 1 : Position, size and nature of image with different positions of object

Sl. No.	Position of lens (cm)	Position of candle (cm)	Size of flame (cm)	Position of image on the screen (cm)	Size of image (cm)	Nature of image (cm)	Relative size of image (cm)
1							
2							
--							
6							

RESULT

1. As the object moves towards the focus of the lens the size of the image increases and it moves away from the focus. In all these positions image is real and inverted and is formed on the other side of the lens.

2. When the object is brought too close to the lens, the image on the other side is not seen.

3. When the object is at a distance less than the focal length, the image formed is virtual, enlarged and erect. It is formed on the same side of the lens as that of the object.

PRECAUTIONS

1. This experiment should be performed at a shaded place where no direct light reaches (preferably in a dark room) otherwise the images may not be distinctly visible.
2. While estimating the rough value of focal length f of the lens by focusing the Sun, do not look at the image directly as it may hurt your eyes.
3. The uprights supporting the optical elements should be rigid and mounted vertically.
4. The aperture of the lens should be small otherwise the image formed will not be distinct.
5. Eye should be placed at a distance more than 25 cm from the image formed on the screen.

DISCUSSION

1. If the object is placed between the optical centre and focus, the image so formed will be virtual in nature, you will not get this image on the screen. Draw the ray diagram.
2. When the candle is placed near the focus, the image is formed at infinity. It may go beyond the end of the table.

SELF ASSESSMENT

1. How does the size of your image formed by a convex lens vary as you move from the other end of the table towards the lens?
2. Where should the object be placed to get a virtual and erect image of the object?
3. What should be the position of the object to get an image on the same side of the lens as the object?
4. How does the position of the image formed by a convex lens vary as you move along the principal axis of the lens from infinity to its focus?
5. What will be the position of the object to get a real image having the same size as the object?

AIM

(ii) To study the nature and size of the image formed by a concave mirror on a screen by using a candle and a screen (for different distances of the candle from the mirror).

APPARATUS AND MATERIAL REQUIRED

An optical bench, candle, match box, a small candlestand, concave mirror of nearly 25 cm focal length, a screen, three uprights (with clamps), metre scale, adhesive tape and spirit level.

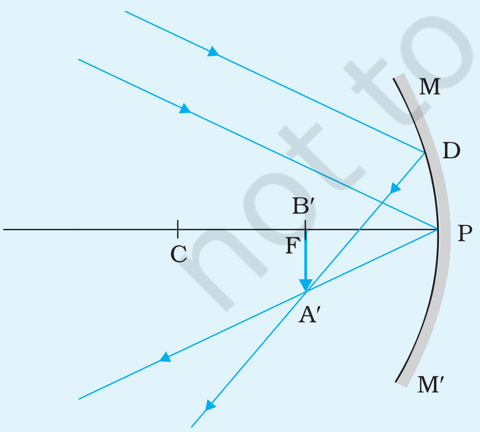
PRINCIPLE

The position, nature and size of the image of an object formed by a concave mirror changes with the position of the object. Figs. A13(ii).1 (a) to (f), show the image formation by placing the object at different positions in front of the mirror in different situations.

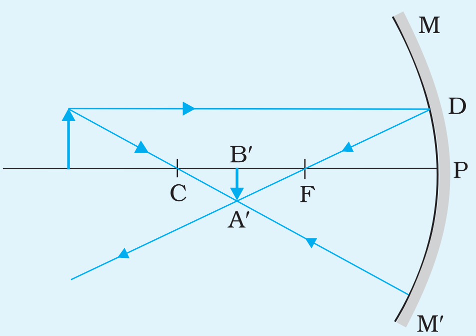
(a) Object is at infinity, i.e., $u = \infty$. A real, inverted and highly diminished image is formed at the principal focus, i.e., $v = f$.

(b) Object is in between infinity and the centre of curvature, i.e., $\infty > u > 2f$. A real, inverted and diminished image lies in between C, the centre of curvature and principal focus, F, i.e., $f < v < 2f$.

(c) Object is at centre of curvature, i.e., $u = 2f$. A real and inverted image is formed at the centre of curvature, i.e., $v = 2f$. The size of the image is equal to the size of object.



(a)



(b)

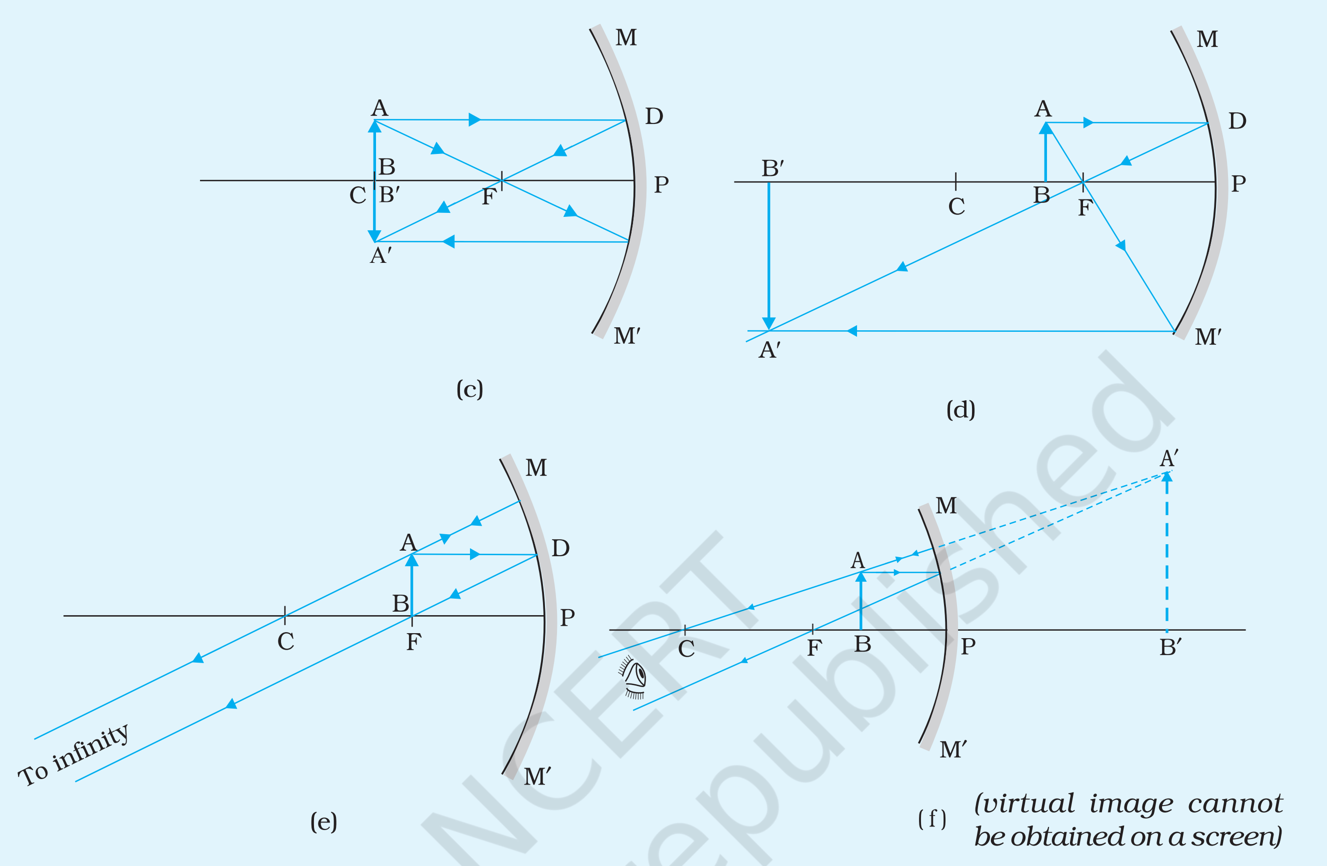


Fig. A 13 (ii).1 (a),(b),(c),(d),(e),(f) *Formation of images by a concave mirror*

(d) Object is in between the centre of curvature and principal focus, i.e., $2f > u > f$. Real, inverted and enlarged image is formed in between C, the centre of curvature and infinity, i.e., $2f < v < \infty$.

(e) Object is at the principal focus F, i.e., $u = f$. A highly enlarged, real and inverted image is formed at infinity, $v = \infty$.

(f) Object is in between the principal focus F and pole of the mirror P, i.e., $f > u > 0$. An enlarged, virtual and erect image is formed behind the mirror.

A real image (always inverted) is the one through which the rays of light actually pass after reflection from concave mirror and which can be formed on a screen. A virtual image (always erect) is the one through which the rays do not actually pass, although they appear to come from it. Thus, the images of an object (e.g., a burning candle) formed for situations illustrated in Figs. A13 (ii).1 (a) to (d) can be focussed on a screen. The size of image may be determined by using a graph paper fixed on the screen.

PROCEDURE

1. Obtain an approximate value of the focal length of the concave mirror by focusing the image of a distant object. It can be found by obtaining a sharp image of the Sun or a tree on a plane wall, or on a sheet of paper and measuring the distance between the mirror and the image with a scale. This distance is an approximate value of the focal length, f of the concave mirror. Twice of this focal length is an approximate value of the radius of curvature of the mirror.

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. Clamp the concave mirror on an upright and fix it near one end of the optical bench such that its principal axis is horizontal and parallel to the optical bench. In this position the mirror would lie in a plane perpendicular to the principal axis of the mirror.

4. Mount a lighted candle vertically on a small candlestand and fix it on an upright. Place this upright near the reflecting surface of the mirror. Adjust the upright so that the height of the bottom of the candle (or top of the candlestand) becomes equal to the height of the pole P of the mirror from the base of the optical bench. In this situation the bottom of the candle (or the top of the candlestand) would lie on the principal axis of the mirror.

5. Mount the screen on another upright and adjust the height of its top equal to the height of pole P from the base of the optical bench. Thus, the position of the screen lies below the principal axis of the mirror.

Note: In situations where $\infty > u > R$; $R > v > f$, the object is kept above the principal axis and screen is kept below the principal axis as shown in Fig. A 13 (ii).2(a).

6. Shift the candle upright to another end of the optical bench so that the distance of the candle from the mirror is much larger than the focal length of the concave mirror. Thus, the position of the candle in front of the mirror can be considered to be distant, i.e., $u >> R$, and the image of the candle will be formed at a position much closer to the principal focus F of the mirror [Fig. A13 (ii).1 (a)] or $v \simeq f$.

7. Read the positions of the mirror, screen and candle uprights on the optical bench metre scale and record the readings in the observation table.

8. Measure height of the lighted candle using the metre scale. Also measure the height of the image formed on screen as done in step 9 of activity 13 (i).

9. Bring the lighted candle close to the centre of curvature C (distance PC = 2 f). Now the image will be formed in between the points C and F, close to 2f. Adjust the position of the screen to get a sharp image [Fig. A 13 (ii). 1(b)].

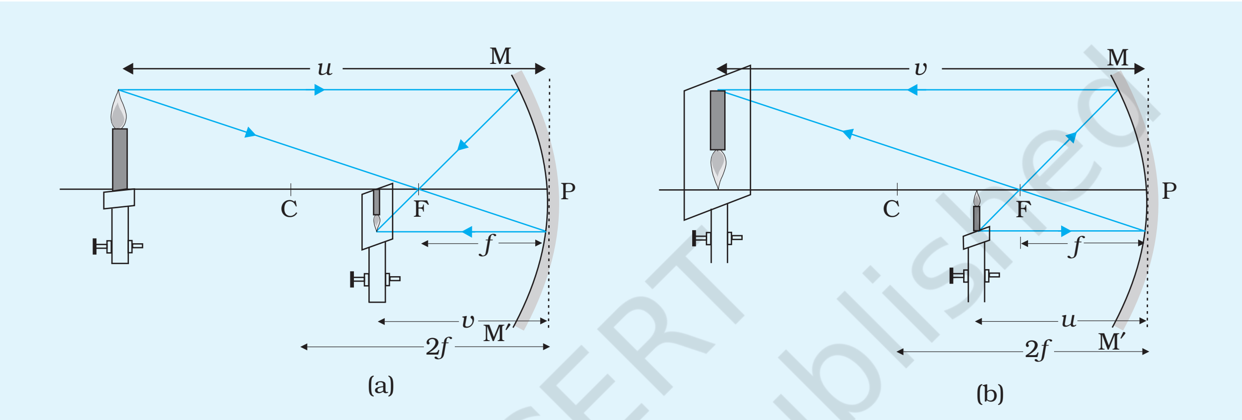


Fig. A 13 (ii). 2 *Real images of a lighted candle formed by a concave mirror (a) u > v; and (b) u < v.*

10. Place the candle at C. Shift the position of the screen near to the principal focus F on the optical bench. Use the rough estimated value of the focal length f of the mirror as determined in Step 1. Make final adjustments to get a sharp image of the lighted candle on the screen. Note the nature of the image.

11. Repeat steps 7 and 8 and record the observations and also note the nature of image formed.

12. Shift the lighted candle such that $R > u > f$. Now the image will be formed in between the point C and infinity, i.e., $\infty > v > R$ [Fig. A13(ii).1(d)]. Now since $u < v$, the candle (object) is placed below the principal axis while the screen is placed above the principal axis, i.e. the top of candle and bottom of the screen lie on principal axis as shown in [Fig. A13 (ii). 2 (b)].

13. Repeat above steps by placing the candle at F and then between F and P. Record your observations in Table A 13 (ii).1.

Note: *When candle is placed at the centre of curvature* C *(i.e., u = R), this method may not be useful for locating the position of image as it is difficult to mount both the screen and candle at the same place on the optical bench.*

OBSERVATIONS

Approximate focal length of the concave mirror =...cm

Table A 13 (ii).1: Nature, size and position of image with different positions of object

Sl. No.	Position of mirror (cm)	Position of candle (cm)	Size of flame (cm)	Position of image on the screen (cm)	Size of image (cm)	Nature of image (cm)	Relative size of image (cm)
1							
2							
--							
6							

RESULT

Observation on the nature, size and position of image shows that

1. The image moves away from the focus as the object is moved towards the focus.
2. The size of the image increases as it moves away from the mirror.
3. If the object is placed between infinity and F the image formed by a concave mirror is real and inverted.
4. If the object is placed between F and pole, the image is formed behind the mirror and it is virtual, erect and enlarged.

PRECAUTIONS

1. This experiment should be performed at a shaded place where no direct light reaches (preferably in a dark room) otherwise the images may not be distinctly visible.
2. While estimating the rough value of focal length f of the mirror by focusing the Sun, do not look at the Sun through the mirror as it may hurt your eyes.
3. The uprights supporting the optical elements should be rigid and mounted vertically.
4. The aperture of mirror should be small otherwise the image formed will not be distinct.
5. Eye should be placed at a distance more than 25 cm from the image being formed on the screen.

6. An error may arise in the observations if the top of optical bench is not horizontal.
7. The general instructions to be followed in all optical bench experiments must be taken care of.
8. The concave mirror should be front-coated. Otherwise multiple reflections coming from the reflecting surface of the mirror will confuse the accurate position of the image.

DISCUSSION

1. You cannot exactly observe the characteristics of the image formed when the object is between focus and pole of the mirror. You can only check by moving the screen in front of it that the image is not formed in front of the mirror. By drawing ray diagram it can be seen that the virtual image is formed behind the mirror.
2. The inferences corresponding to $u=\infty$ and $u=f$ also be elicited by the trends you observe and drawing ray diagrams, because, the object and image (respectively) are situated outside the range of optical bench.
3. The situation corresponding to $u=2f$, may also be difficult to locate because you have to place the candle and the screen at the same position.

SELF ASSESSMENT

1. The focal length of a concave mirror is 20 cm, what is its radius of curvature?
2. When an object is placed at 30 cm in front of a concave mirror, image of the same size is formed. What is the focal length of the mirror?
3. Focal length of a concave mirror is 30 cm. What will be the characteristics of the image formed, when the object is placed at a distance of 40 cm in front of the mirror?
4. What is the effect on the size and intensity of the image formed when the lower half of the concave mirror is painted black?
5. Is it possible to get a virtual image on the screen? If so, how?
6. In a similar experiment using lenses, the images look a little coloured, unlike this experiment. What is the reason for this?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

Using a plane mirror and a single pin determine the focal length of a given convex lens.

ACTIVITY 14

AIM

To obtain a lens combination with specified focal length by using two lenses from a given set of lenses.

APPARATUS AND MATERIAL REQUIRED

A set of convex lenses of known powers, optical bench with uprights and screen, a source of light providing a parallel beam of light (a collimator).

PRINCIPLE

A parallel beam of light parallel to principal axis after refraction through a lens either focus at a point or appears to diverge from a point on the principal axis called the focus point. The distance from the optical centre to the focal point is called the focal length.

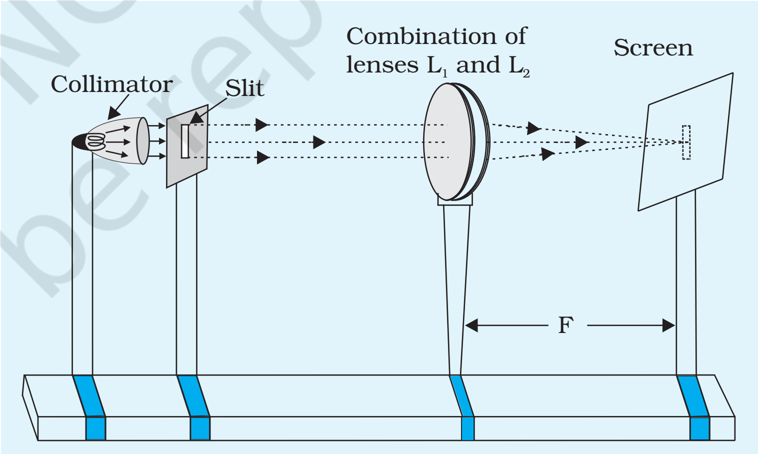


Fig. A 14.1 (a) *Focal length of combination of lenses*

Power of lens

The ability of a lens to converge or diverge the rays passing through it is called the power of the lens

$$\text{Power} = \frac{1}{\text{focal length}(f)}$$

Its SI unit is Dioptre. Power of a convex lens is taken as positive. Two or more lenses, placed in contact together to have a common principal axis, form a lens combination. If f_1, f_2, ... f_n be the focal length of individual lens and F be the focal length of the combination, then

$$\frac{1}{F}=\frac{1}{f_1}+\frac{1}{f_2}+\ldots+\frac{1}{f_n} \quad \text{or}$$

$P = P_1 + P_2 + \ldots + P_n$, where P is the power of the lens combination and P_1, P_2, ... P_n are the powers of the individual lenses. Fig. A 14.1(a).

PROCEDURE

1. Calculate the power of the combination of two lenses corresponding to the required focal length.
2. Select a lens from the given set of lenses whose power is smaller than that of the combination of lenses to be prepared, (if only convex lenses are provided).
3. Calculate the power of unknown convex lens to be kept in contact with the lens of known focal length to obtain a combination of lenses of desired focal length. Select the lens whose power is close to the calculated power from the given set of lenses.
4. Set up the optical bench on a horizontal table. Adjust the collimator to direct parallel beam of light along the optical bench. In case collimator is not available, a plane mirror may be used to direct sunlight along the optical bench [Fig. A 14.1 (b)] and illuminate a slit with it.

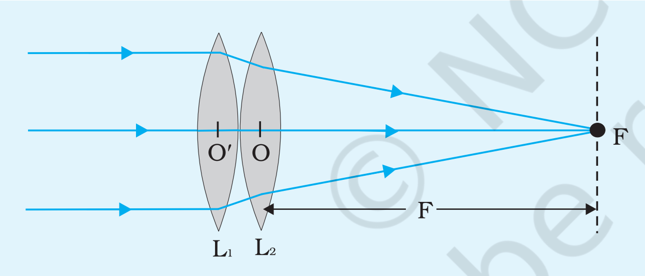


Fig. A 14.1 (b) *Focussing parallel beam of light on combination of lenses*

5. Place the two lenses on the uprights such that they are in contact with each other. An upright that can hold two lenses in contact may also be used or the same may be improvised by fixing the lenses on grooves carved on a thermocole sheet.
6. Direct a parallel beam of light on the combination of lenses and obtain a sharply focussed image of the source of light on a screen placed on the other side of the lenses. This can be done by adjusting the distance between the combination of lenses and screen.
7. Measure the distance of the screen from both the lenses and record it in a table.
8. Repeat the activity atleast three times by changing the position of the lens combination on the optical bench. Record your observations in each case.

OBSERVATIONS

Focal length of lens $L_1 = f_1$

Focal length of lens $L_2 = f_2$

Calculated focal length of lens combination $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$

Least count of the scale of the optical bench = ...mm.

Table A 14.1: Focal length of combination of lenses

Sl. No.	Distance of first lens from the screen d_1 (cm)	Distance of second lens from the screen d_2 (cm)	Mean distance of screen from lens combination $\frac{d_1 + d_2}{2} = F$ (cm)
1			
2			
3			

CALCULATIONS

The mean distance of the screen from the lens combination is a measure of its focal length. Take average of all readings as the focal length of the combination determined by the experiment.

RESULT

Measured value of focal length of lens combination =...cm

Difference between measured value of focal length and the calculated focal length =...cm

The difference between the two could be due to experimental error.

SOURCES OF ERROR

1. Thickness of the lenses may cause an error.
2. The peripheral region of the lenses are not in contact.
3. Spherical aberration of the lenses may cause an error in locating the position of the sharp image, i.e., the exact focal length.

DISCUSSION

1. A source rendering parallel beam of light may be obtained by placing a torch bulb at the focus of a convex lens of known focal length.

2. You can make lens combinations using a pair of lenses separated by a distance d and adjusting the separation between them. You may obtain the combination of desired focal length using the formula,

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

What is the range of focal lengths you may obtain this way?

SELF ASSESSMENT

1. A convex lens of focal length 20 cm is put in contact with a concave lens of focal length 10 cm. What will be the effective focal length of the combination?

2. If a convex lens is dipped completely in water, what will be the effect on its focal length?

3. If two lenses of focal lengths f_1 and f_2 are placed distance d apart, is the formula $\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2}$ still valid? If not, give the modified formula. Will the focal length of the combination be (i) $< F$ (ii) $> F$?

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. A person having refractive error is able to see distant objects clearly but is not able to read a book. We find that she can read the book clearly on using a combination of lenses of focal lengths 2, 2/3m and -1m, available in the laboratory. What should be the power of the lens to be prescribed for such a person?

2. Select a pair of lenses whose combination (i) will act as a converging lens (ii) will not act as a converging lens.