EXPERIMENT

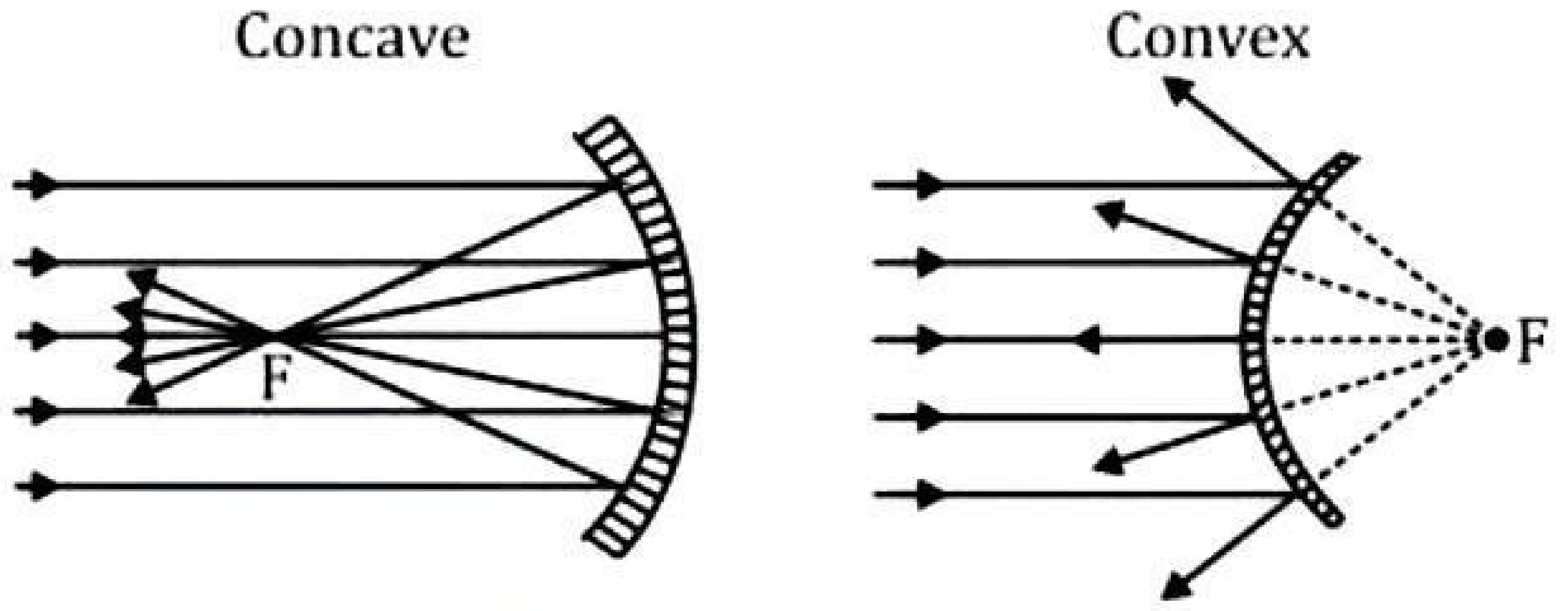
AIM

To find the value of v for different values of u in the case of a concave mirror and to find the focal length.

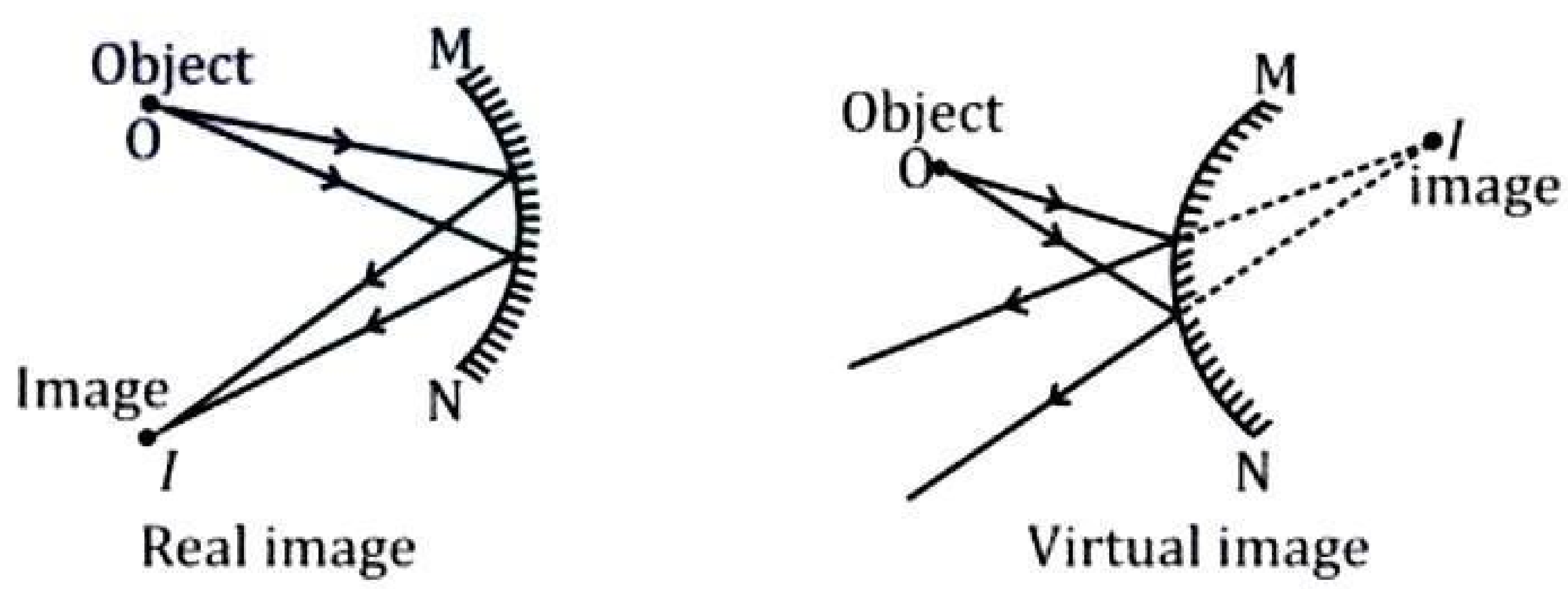
MATERIAL REQUIRED

An optical bench, three uprights, a concave mirror with a mirror holder, two needles, a spirit level and a meter scale.

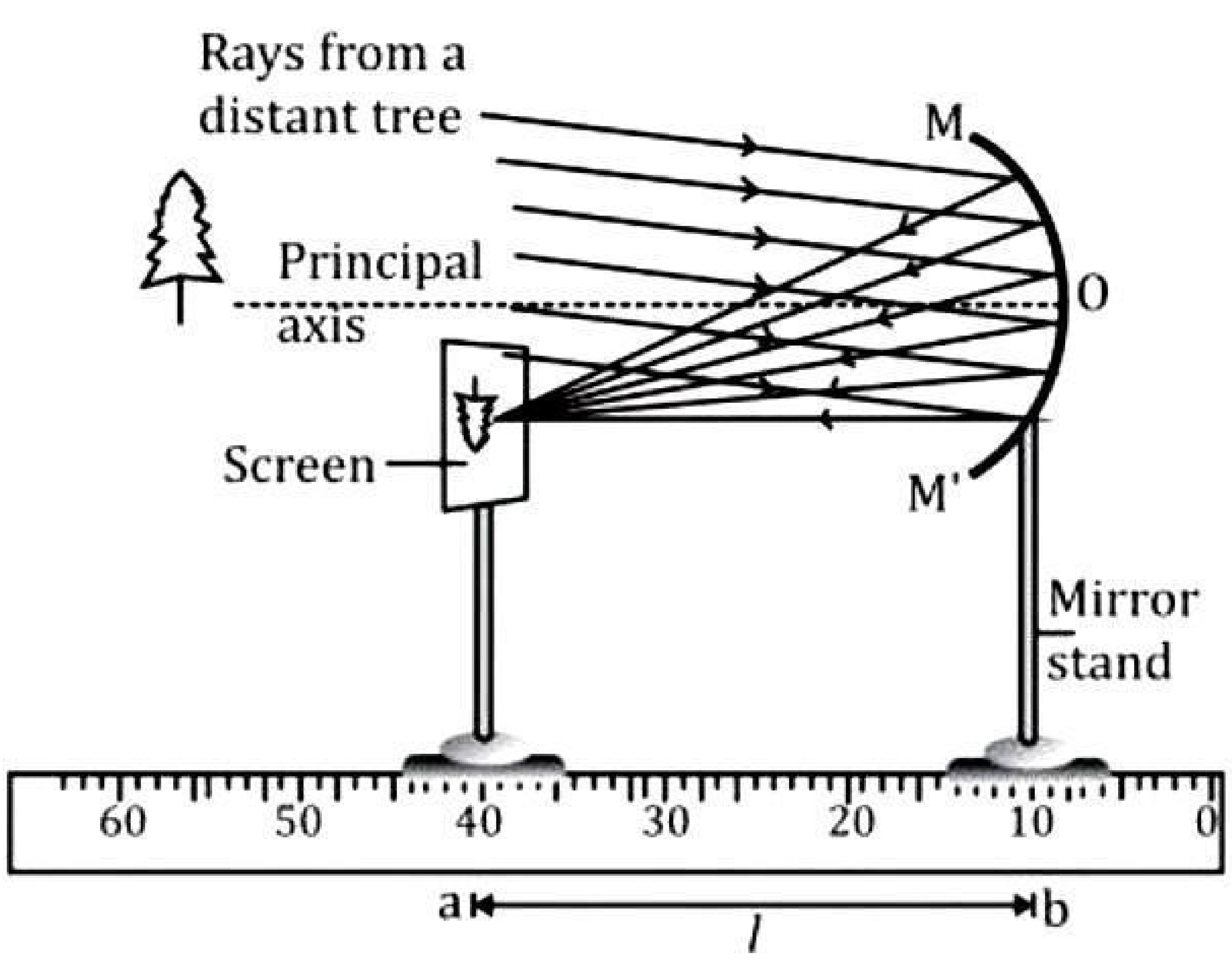
DIAGRAM



Spherical mirror



Ray diagram for image formation by



THEORY

1. **Reflection** is the phenomenon of returning light incident on a shiny surface into the same medium.

2. **Laws of reflection:**
   - **(i)** The incident ray, the normal at the point of incidence, and the reflected ray all lie in the same plane.
   - **(ii)** The angle of incidence is equal to the angle of reflection.
3. **Some important terms associated with spherical mirrors:**
   - **(i) An aperture** of the mirror is the angle θ subtended by its periphery at its centre of curvature.
   - **(ii) Pole** is the geometrical centre of the surface of the mirror.
   - **(iii) The Centre of curvature** (C) is the centre of the hollow sphere of which the mirror is a part and the radius of this sphere PC is called the radius of curvature (R) of the mirror.
   - **(iv) The principal axis** is the line PC passing through the pole P and the centre of curvature C of the mirror.
4. **Focus and focal length:**
   The rays of light incident parallel and close to the principal axis of a concave mirror, after reflection, converge to a point *F* on the principal axis of a concave mirror or appear to diverge from a point *F* on the principal axis of a convex mirror. This point *F* is called the focus of the spherical mirror. In the case of a concave (or converging) mirror, the focus is real while in the case of a convex (or diverging) mirror focus is virtual. The distance between focus *F* and the pole *P* is called the focal length of the mirror represented by (f).
5. **A focal plane is a plane normal to the principal axis passing through its principal focus.**
   For a spherical mirror of small aperture, the focal length of a spherical mirror (concave or convex) (f) is half of its radius of curvature (R), i.e., $f = \frac{R}{2}$
6. **Sign convention for spherical mirrors: According to the new cartesian sign convention, all distances are measured from the pole.**
   - **(i)** On the axis, the distances in the direction of incidence will be taken as positive and the distances against it will be taken as negative, Thus, if the object is placed to the left of the mirror-object distance will always be negative, focal length and radius of curvature of a concave mirror will be negative and the focal length and radius of curvature of a convex mirror will be positive.
   - **(ii)** Distances above the principal axis will be taken as positive and below it as negative. Thus, the inverted image size will be negative, and the erect image size will be positive.
7. **Rules for the formation of images from a concave mirror:**
   - **(i)** A ray of light incident on a concave mirror parallel to the principal axis passes through its focus after reflection from the mirror.
   - **(ii)** A ray of light incident on the concave mirror after passing through its focus becomes parallel to the principal axis after reflection from the mirror.
   - **(iii)** A ray of light incident on the concave mirror after passing through the centre of curvature of the mirror is reflected along the same path.
   - **(iv)** A ray of light that is incident at the pole of the mirror is reflected making the same angle as the principal axis on the other side.

     The relation between object distance (u), the image distance (v), and the focal length (f) of a concave mirror is given by

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

$$\boxed{f = \frac{uv}{u + v}}$$

The relation is known as the mirror formula.

PROCEDURE

1. Find the rough focal length of the concave mirror. For this, obtain a sharp and clear image of a distant object (trees/pole/building, etc.) on your laboratory wall adjusting the distance between the concave mirror and the wall and sliding the mirror along the meter scale. Measure the distance between the mirror and the wall on the meter scale. It gives the approximate focal length of the concave mirror.
2. Now place three uprights on the optical bench, one holding the concave mirror and the rest two holding two needles. Place the mirror upright on the zero ends of the optical bench and the other two uprights near the other end. Now clamp the mirror in the holder such that the reflecting surface is facing towards needles.
3. With the help of spirit level and levelling screws, level the bench so that the mirror and pins are held vertically. Now adjust the principal axis of the mirror parallel to the optical bench. Note the position of the index mark on the base of the mirror upright carefully.
4. Take a thin optical needle as an object needle, O and mount it in the second upright between the mirror and image needle. Move this upright approximately, at a distance of 1.5 times the rough focal length of the concave mirror. Adjust the height of the object needle, O so that its tip lies along the horizontal line through the pole of the concave mirror. Since the object is in a position between the focal point F and the centre of curvature C, a real and inverted image of the object needle will be formed beyond the centre of curvature C.
5. Now take a thick optical needle, as the imaging needle, I in the third upright and adjust its position, such that the tip of the inverted image of the object needle and the imaging needle coincide. To ensure this move your head to and from sideways and see that the tips remain coincident, i.e., there is no parallax. In no parallax position, the imaging needle locates the position of the image of the object needle.
6. Note the position of the index mark on the base of the object needle upright and image the needle upright carefully.
7. Repeat the above steps for five different positions of the object needle keeping it between f and 2f and record the observations in the table.
8. Measure the actual length of the knitting needle with the help of a meter scale. Let it be x. Adjust the distance between the tip of the object needle and the pole of the mirror equal to x and read the position between the index marks of these two uprights. Let it be y. Then index correction in the measurement of u is $(x - y)$. Similarly, determine the index correction for the imaging needle.

   NOTE: In case you find difficulty in locating an image corresponding to five positions of the object needle between f nd 2f, you can consider the imaging needle as an object needle at more than 2f and find the position of the image between f and 2f.

OBSERVATION

1. Least count of the meter scale = __________ cm
2. The rough focal length of the concave mirror = ___________cm.
3. The actual length of the knitting needle, x = ____________cm.
4. On placing the knitting needle in between the:

   (a) Object needle and the mirror, the observed distance, y = _________ cm

   (b) Image needle and the mirror, the observed distance, z = __________ cm
5. Index correction for object distance, $I_u = x - y =$ _________cm
6. Index correction for image distance, $I_v = x - z =$ _________ cm

TABLE FOR THE FOCAL LENGTH OF THE CONCAVE MIRROR

No. of obser-va-tions	Position of			Distance between the mirror, M and object pin, O		Distance be-tween mirror, M and image pin, I		Focal length $f = \frac{uv}{u+v}$	Mean (cm)
	Mir-ror, M (cm)	Object pin, O (cm)	Image pin, I (cm)	Ob-served (cm)	Corrected, v (cm)	Ob-served (cm)	Cor-rected, v (cm)		
1.									
2.									
3.									
4.									
5.									

Mean f =……….cm

CALCULATION

To determine the focal length from the graph, plot a u vs v graph or $\frac{1}{u}$ vs $\frac{1}{v}$ graph choosing the same scale for x-axis as well as for y-axis in the third quadrant (according to sign convention both u and v are negative).

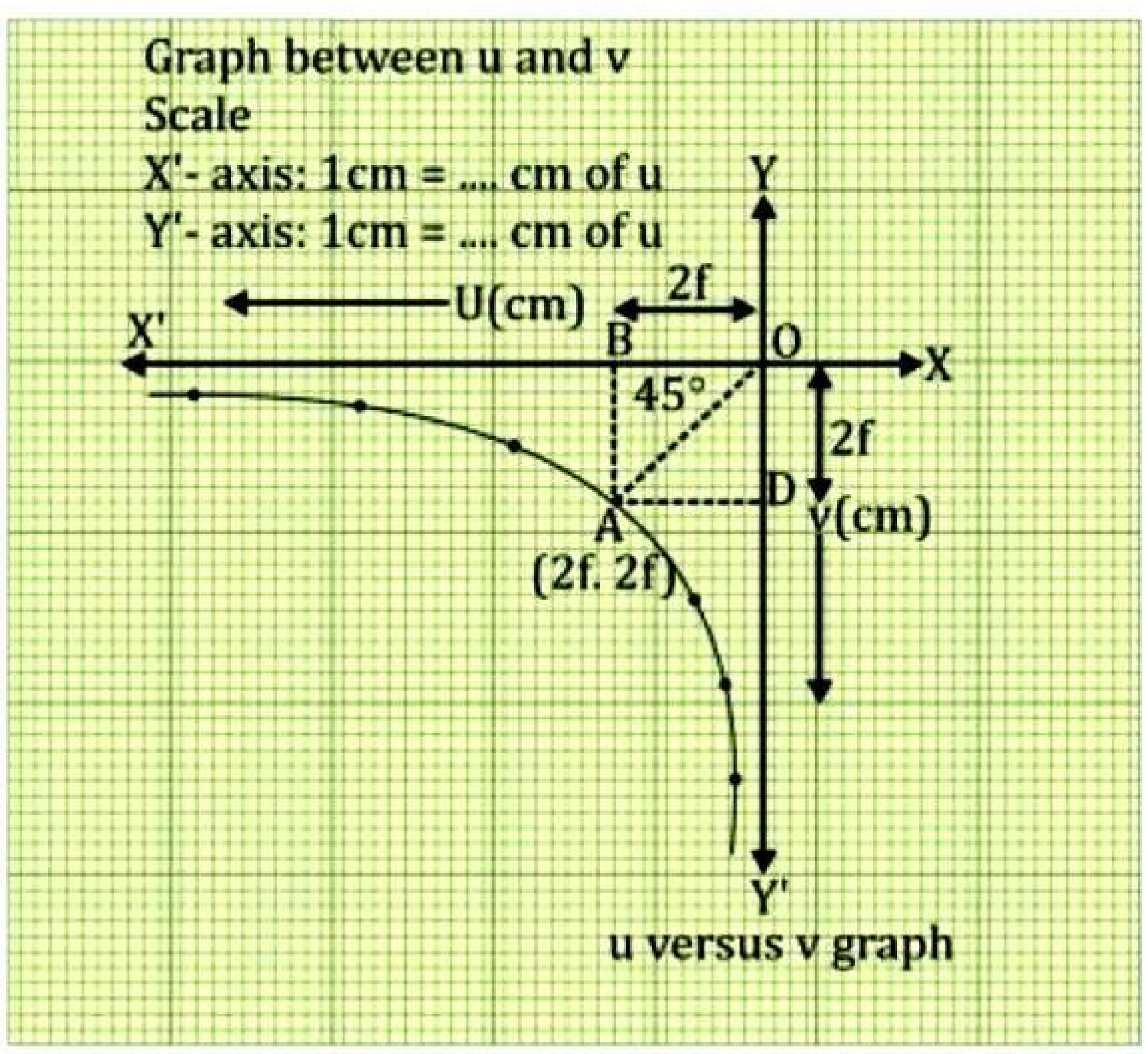
(i) The u vs v graph will be a rectangular hyperbola as shown in Fig.

(ii) Draw the angle bisector of $\angle X'OY'$ which meets the graph at point P. The coordinates of point P are $(-2f, -2f)$. Draw perpendiculars on OX' and OY' axes which cut at Q on OX' axis and R on OY' axis. The distance $OQ = OR = -2f$.

$\therefore$ The focal length of the concave mirror, $f = -\frac{OQ}{2} = -\frac{OR}{2}$

(iii) $\frac{1}{u}$ vs $\frac{1}{v}$ the graph will be a straight line as shown in Fig.

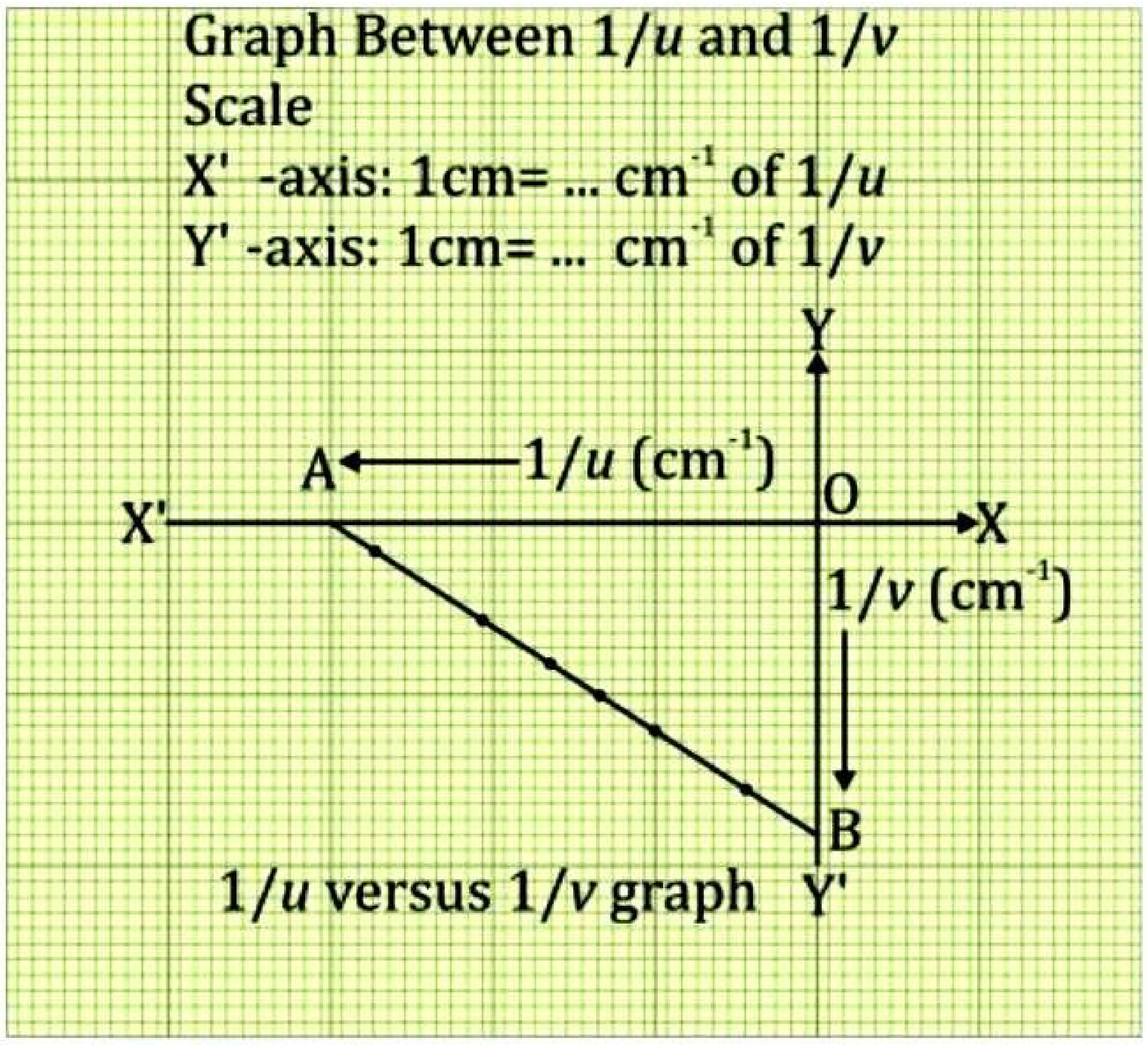
Using the mirror formula $\frac{1}{f} = \frac{1}{v} + \frac{1}{u}$



At P, $\frac{1}{v} = 0 \therefore \frac{1}{f} = \frac{1}{u} = OP$ or $f = -\frac{1}{OP}$

At Q, $\frac{1}{u} = 0 \therefore \frac{1}{f} = \frac{1}{v} = OQ$ or $f_1 = -\frac{1}{OQ} = \cdots cm$

Similarly, $f_1 = -\frac{1}{OP} =$ ....cm



1/u versus 1/v graph

Mean $f = \frac{f_1 + f_2}{f} =$..........cm

RESULT

1. The focal length of a given concave mirror by computation from the table, f = ⋯ cm
2. From u vs v graph, f =.......cm
3. From $\frac{1}{u}$ vs $\frac{1}{v}$ graph, f = ...cm

Note: You may be asked to go by any of these three methods for finding focal length.

PRECAUTIONS

1. The needles should be sharp and thin.
2. The uprights must be vertical.
3. The tips of the needles and the centre of the concave mirror should be at the same height.
4. Index correction for object distance from the pole of the mirror and the image distance from the pole of the mirror should be properly determined and applied.
5. The images formed should be sharp.
6. To locate the position of the image, the observer must place his/her eye at a distance of about 30 cm behind the imaging needle.

SOURCES OF ERROR

1. The uprights may not be vertical.
2. The parallax may not be removed properly.
3. Index correction may not be applied properly.
4. Personal error.

VIVA- VOCE

Q 1. What is the aim of the experiment allotted to you?

Ans. To find the value of v for different values of u in the case of a concave mirror and to find the focal length either by plotting a graph between (i) u and v, and (ii) $\frac{1}{u}$ and $\frac{1}{v}$ or by direct calculations.

Q 2. What is reflection?

Ans. Reflection is the phenomenon of returning light into the same medium after striking a surface.

Q 3. How many types of reflection do you know?

Ans. There are usually two kinds of reflection
(i) regular reflection and (ii) irregular reflection.

Q 4. How will you differentiate between regular reflection and irregular reflection?

Ans. In regular reflection, if a parallel beam of light is incident on a plane mirror, the reflected light beam is also parallel and is in a fixed direction. In irregular reflection, if a parallel beam of light is incident on a rough surface, the reflected light spreads in different directions.

Q 5. What is the relation between the focal length and radius of curvature of a spherical mirror?

Ans. The focal length of a spherical mirror,

$$f = \frac{\text{Radius of curvature (R)}}{2}$$

Q 6. Define the principal axis.

Ans. The principal axis of a spherical mirror is the straight line joining the pole of the mirror to its centre of curvature.

Q 7. What do you mean by the focus of a concave mirror?

Ans. The focus of a concave mirror is a point on the principal axis at which the light ray's incident on the mirror parallel to the principal axis meets after reflection from the mirror.

Q 8. How will you define the focal length of a spherical mirror?

Ans. Focal length is the distance between the pole and the focus of the spherical mirror.

Q 9. What happens if a ray of light is incident on the concave mirror parallel to the principal axis?

Ans. A ray of light incident on the concave mirror parallel to the principal axis passes through the focus after reflection from the mirror.

Q 10. Name the mirror which may produce (i) a diminished real image, (ii) a diminished virtual image.

Ans. (i) Concave mirror,
(ii) Convex mirror.

Q 11. Can you differentiate between real and virtual images?

Ans.
1. Real image is formed due to the actual intersection of the reflected rays while a virtual image is
2. formed when reflected rays appear to meet.
3. Real image of a real object is always inverted while the virtual image of a real object is always erect.
4. Real images can be taken on the screen while the virtual image cannot be taken on the screen.