6 Refractive Index of Water using Concave Mirror

As shown in Fig. 11.6(*a*), consider a concave mirror placed on a horizontal surface with its principal axis vertical. Suppose the tip of an object needle *O* lies at its centre of curvature *C*. The rays of light *CP* and *CQ* fall normally on the mirror and retrace their paths after reflection forming a real and inverted image *I* at C. For no parallax between the needle and its image,

$$u = v = R = PC$$

Take small amount of water (transparent liquid) in the concave mirror. The object needle has to be lowered to a new position *C'* for no parallax between it and its image.

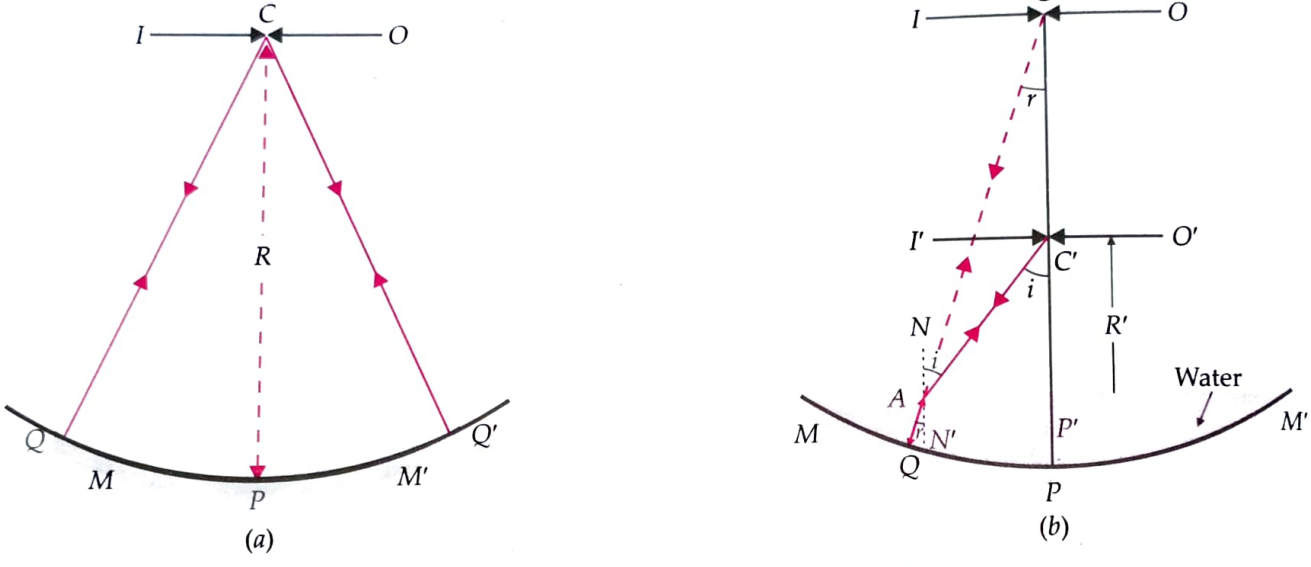

Fig. 11.6 Formation of image of an object *O* by a concave mirror *MM'* placed at its centre of curvature. (*a*) Mirror without water and (*b*) Mirror with some water.

The incident ray $C'A$ refracts along AQ in water falling normally on the mirror. The reflected ray retraces the same path QAC' forming real and inverted image I' at C'. So distance PC' is the apparent radius of curvature of the water-filled concave mirror. As AQ is normal to the mirror, QA when produced must pass through the centre of curvature C. Let i and r be angles of incidence and refraction at A.

$$^{a}\mu_{w} = \frac{\sin i}{\sin r} = \frac{AP'/AC'}{AP'/AC} = \frac{AC}{AC'}$$

For normal incidence, A lies close to P'. For little quantity of water in the concave mirror, depth PP' can be neglected as compared to PC or PC'.

$$\therefore \quad ^{a}\mu_{w} = \frac{P'C}{P'C'} = \frac{PC}{PC'}$$

or
$$^{a}\mu_{w} = \frac{R}{R'} = \frac{\text{Actual radius of curvature}}{\text{Apparent radius of curvature}}$$

Thus, we can determine refractive index of any transparent liquid using this method.

EXPERIMENT B7

AIM

To find the refractive index of a liquid (water) using a concave mirror.

APPARATUS AND MATERIAL REQUIRED

A concave mirror of large focal length (≃25 cm), an optical needle, an iron stand with clamp arrangement, a metre scale, a plumb line and water.

THEORY/WORKING FORMULA

Using Snell's law, for light ray undergoing refraction from air to water,

$$^{a}\mu_{w} = \frac{\sin i}{\sin i} = \frac{AP'/AC'}{AP'/AC} = \frac{AC}{AC'}$$

For normal incidence A lies close to P'. For little quantity of water in the concave mirror, depth PP' can be neglected as compared to PC or $P'C$.

$$\therefore \quad ^{a}\mu_{w} = \frac{P'C}{P'C'} = \frac{PC}{PC'} \qquad \text{or} \quad ^{a}\mu_{w} = \frac{R}{R'} = \frac{\text{Actual radius of curvature}}{\text{Apparent radius of curvature}}$$

RAY DIAGRAM

See Fig. 11.6(b)

PROCEDURE

1. Looking through the window of your laboratory, turn the reflecting surface of the concave mirror towards a distant building/a tree. Obtain bright and clear image of the distant object on a plane wall of the laboratory. Measure the distance between the mirror and the image which gives rough focal length of the concave mirror.
2. Place the concave mirror on a horizontal surface with its face horizontal and principal axis vertical. The mirror should be at such a level so that you can conveniently look upon it from above.
3. Clamp an optical needle horizontally in an iron stand. Adjust position of the tip of the needle just above the point P or on the principal axis of the concave mirror.

4. Adjust the distance of the clamped needle equal to twice the rough focal length f from the mirror.
5. Keeping the eye at more than 25 cm above the needle, look for the real and inverted image of the needle in the mirror. Adjust the needle so that the real image of its tip coincides with the tip itself.
6. Adjust the position of the needle till there is no parallax between the needle and its inverted image.
7. Using a metre scale and a plumb line, measure the vertical distance PC between the pole of the mirror and the tip of the needle which is at the centre of curvature C. This distance will be the real radius of curvature of the mirror.
8. Now pour a small quantity of water on the reflecting surface of the mirror so that it forms a thin layer.
9. Lower the optical needle slowly and again adjust its position till there is no parallax between the needle and its real image formed by the water-filled mirror.
10. Measure the vertical distance PC' of the tip of the needle from the pole of the mirror. This distance will be the apparent radius of curvature of the water-filled mirror.

NOTE The distances PC and PC' can be measured by clamping a metre scale *vertically* by the side of the mirror with the help of a plumb line.

11. Repeat the experiment (steps 4 to 10) at least two more times. Record all these observations in a tabular form.

OBSERVATIONS AND CALCULATIONS

Rough focal length of the concave mirror, $f =$ _____ cm

Approximate value of radius of curvature, $R = 2f =$ _____ cm

Table 11.2 : Real and apparent radii of curvature of concave mirror

S.No.	Distance of the tip of the needle from the pole P with		Refractive of water $^{a}\mu_{w} = \frac{R}{R'} = \frac{PC}{PC'}$
	empty concave mirror $R = PC$ (cm)	water-filled concave mirror $R' = PC'$ (cm)	
1.			
2.			
3.			

Mean refractive index of water, $^{a}\mu_{w} =$ _____

RESULT

Refractive index of water using concave mirror, $^{a}\mu_{w} =$ _____

Actual value from standard tables = _____

Percentage error $= \frac{\text{Actual value} - {}^{a}\mu_{w}}{\text{Actual value}} \times 100 =$ _____ %

PRECAUTIONS

1. The principal axis of the concave mirror should be vertical.
2. The optical needle should be clamped horizontally so that its tip lies just above the pole of the mirror and on its principal axis.

3. The concave mirror should be thin and of large radius of curvature (20 cm to 25 cm).
4. Distances should be measured from the pole of the mirror and not from the water surface.
5. Parallax between the needle and its image should be removed tip to tip.
6. Eye should be kept at a distance of more than 25 cm from the optical needle.
7. The quantity of water taken in the concave mirror should be just sufficient to form a thin layer with horizontal water surface. In case of very small quantity of water, the surface may be curved due to surface tension.

SOURCES OF ERROR

1. Thickness of the mirror may be large.
2. Parallax might not have been removed completely.
3. Measurement of distance PC or PC' may not be exactly vertical.