EXPERIMENT 3

AIM

To determine the radius of curvature of a given spherical surface by a spherometer.

APPARATUS AND MATERIAL REQUIRED

A spherometer, a spherical surface such as a watch glass or a convex mirror and a plane glass plate of about 6 cm × 6 cm size.

DESCRIPTION OF APPARATUS

A spherometer consists of a metallic triangular frame F supported on three legs of equal length A, B and C (Fig. E 3.1). The lower tips of the legs form three corners of an equilateral triangle ABC and lie on the periphery of a base circle of known radius, *r*. The spherometer also consists of a central leg OS (an accurately cut screw), which can be raised or lowered through a threaded hole V (nut) at the centre of the frame F. The lower tip of the central screw, when lowered to the plane (formed by the tips of legs A, B and C) touches the centre of triangle ABC. The central screw also carries a circular disc D at its top having a circular scale divided into 100 or 200 equal parts. A small vertical scale P marked in millimetres or half-millimetres, called main scale is also fixed parallel to the central screw, at one end of the frame F. This scale P is kept very close to the rim of disc D but it does not touch the disc D. This scale reads the vertical distance which the central leg moves through the hole V. This scale is also known as pitch scale.

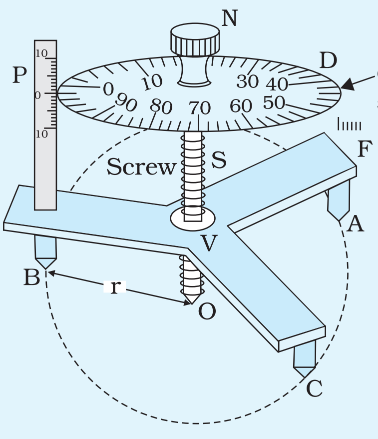

Fig. E 3.1: *A spherometer*

TERMS AND DEFINITIONS

Pitch: It is the vertical distance moved by the central screw in one complete rotation of the circular disc scale.

Commonly used spherometers in school laboratories have graduations in millimetres on pitch scale and may have100 equal divisions on circular disc scale. In one rotation of the circular scale, the central screw advances or recedes by 1 mm. Thus, the pitch of the screw is 1 mm.

Least Count: Least count of a spherometer is the distance moved by the spherometer screw when it is turned through one division on the circular scale, *i.e.*,

$$\text{Least count of the spherometer} = \frac{\text{Pitch of the spherometer screw}}{\text{Number of divisions on the circular scale}}$$

The least count of commonly used spherometers is 0.01 mm. However, some spherometers have least count as small as 0.005 mm or 0.001 mm.

PRINCIPLE

FORMULA FOR THE RADIUS OF CURVATURE OF A SPHERICAL SURFACE

Let the circle AOBXZY (Fig. E 3.2) represent the vertical section of sphere of radius R with E as its centre (The given spherical surface is a part of this sphere). Length OZ is the diameter (= 2R) of this vertical section, which bisects the chord AB. Points A and B are the positions of the two spherometer legs on the given spherical surface. The position of the third spherometer leg is not shown in Fig. E 3.2. The point O is the point of contact of the tip of central screw with the spherical surface.

Fig. E 3.3 shows the base circle and equilateral triangle ABC formed by the tips of the three spherometer legs. From this figure, it can be noted that the point M is not only the mid point of line AB but it is the centre of base circle and centre of the equilateral triangle ABC formed by the lower tips of the legs of the spherometer (Fig. E 3.1).

In Fig. E 3.2 the distance OM is the height of central screw above the plane of the circular section ABC when its lower

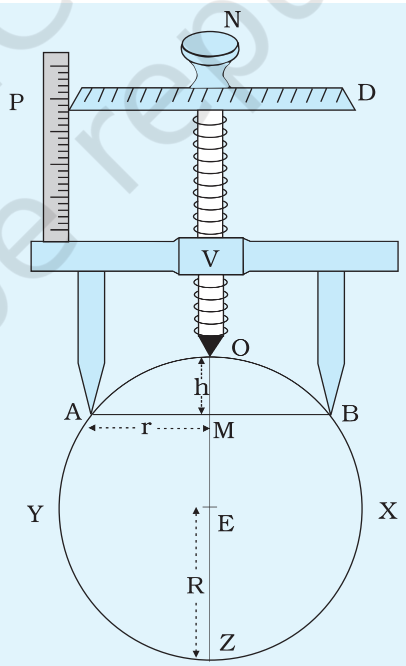

Fig. E 3.2: *Measurement of radius of curvature of a spherical surface*

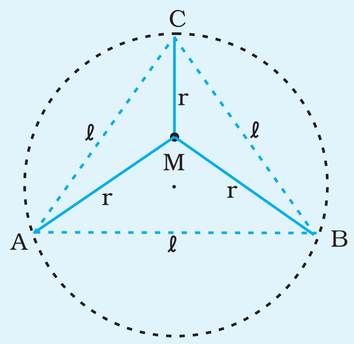

Fig. E 3.3: *The base circle of the spherometer* tip just touches the spherical surface. This distance OM is also called sagitta. Let this be h. It is known that if two chords of a circle, such as AB and OZ, intersect at a point M then the areas of the rectangles described by the two parts of chords are equal. Then

$$AM.MB = OM.MZ$$

$$(AM)^2 = OM\ (OZ - OM) \text{ as } AM = MB$$

Let EZ (= OZ/2) = R, the radius of curvature of the given spherical surface and AM = r, the radius of base circle of the spherometer.

$$r^2 = h\ (2R - h)$$

Thus, $$R = \frac{r^2}{2h} + \frac{h}{2}$$

Now, let l be the distance between any two legs of the spherometer or the side of the equilateral triangle ABC (Fig. E 3.3), then from geometry we have

Thus, $r = \frac{l}{\sqrt{3}}$, the radius of curvature (R) of the given spherical surface can be given by

$$R = \frac{l^2}{6h} + \frac{h}{2}$$

PROCEDURE

1. Note the value of one division on pitch scale of the given spherometer.
2. Note the number of divisions on circular scale.
3. Determine the pitch and least count (L.C.) of the spherometer. Place the given flat glass plate on a horizontal plane and keep the spherometer on it so that its three legs rest on the plate.
4. Place the spherometer on a sheet of paper (or on a page in practical note book) and press it lightly and take the impressions of the tips of its three legs. Join the three impressions to make an equilateral triangle ABC and measure all the sides of ΔABC. Calculate the mean distance between two spherometer legs, l.

   In the determination of radius of curvature R of the given spherical surface, the term l^2 is used (see formula used). Therefore, great care must be taken in the measurement of length, l.

5. Place the given spherical surface on the plane glass plate and then place the spherometer on it by raising or lowering the central screw sufficiently upwards or downwards so that the three spherometer legs may rest on the spherical surface (Fig. E 3.4).

6. Rotate the central screw till it gently touches the spherical surface. To be sure that the screw touches the surface one can observe its image formed due to reflection from the surface beneath it.

7. Take the spherometer reading h_1 by taking the reading of the pitch scale. Also read the divisions of the circular scale that is in line with the pitch scale. Record the readings in Table E 3.1.

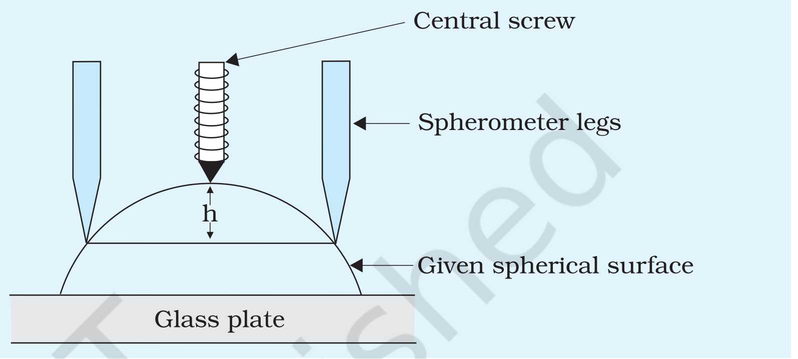

Fig.E 3.4: *Measurement of sagitta h*

8. Remove the spherical surface and place the spherometer on plane glass plate. Turn the central screw till its tip gently touches the glass plate. Take the spherometer reading h_2 and record it in Table E 3.1. The difference between h_1 and h_2 is equal to the value of sagitta (h).

9. Repeat steps (5) to (8) three more times by rotating the spherical surface leaving its centre undisturbed. Find the mean value of h.

OBSERVATIONS

A. Pitch of the screw:

(i) Value of smallest division on the vertical pitch scale = ... mm

(ii) Distance q moved by the screw for p complete rotations of the circular disc = ... mm

(iii) Pitch of the screw $(= q / p)$ = ... mm

B. Least Count ($L.C.$) of the spherometer:

(i) Total no. of divisions on the circular scale (N) = ...

(ii) Least count (L.C.) of the spherometer

$$= \frac{\text{Pitch of the spherometer screw}}{\text{Number of divisions on the circular scale}}$$

$$\text{L.C.} = \frac{\text{Pitch of the screw}}{N} = \ldots \text{ cm}$$

C. Determination of length l (from equilateral triangle ABC)

(i) Distance AB = … cm

(ii) Distance BC = … cm

(iii) Distance CA = … cm

$$\text{Mean } l = \frac{AB + BC + CA}{3} = \ldots \text{ cm}$$

Table E 3.1 Measurement of sagitta *h*

S. No.	Spherometer readings								$(h_1 - h_2)$
	With Spherical Surface				Horizontal Plane Surface				
	Pitch Scale reading x (cm)	Circular scale division coinciding with pitch scale y	Circular scale reading $z = y \times$ L.C (cm)	Spherometer reading with spherical surface $h_1 = x + z$ (cm)	Pitch Scale reading x' (cm)	Circular scale division coinciding with pitch scale y'	Circular scale reading $z' = y \times$ L.C. (cm)	Spherometer reading with spherical surface $h_2 = x' + z'$ (cm)	

Mean h = … cm

CALCULATIONS

A. Using the values of l and h, calculate the radius of curvature R from the formula:

$$R = \frac{l^2}{6h} + \frac{h}{2};$$

the term $h/2$ may safely be dropped in case of surfaces of large radii of curvature (In this situation error in $\left(\frac{l^2}{6h}\right)$ is of the order of $h/2$).

RESULT

The radius of curvature R of the given spherical surface is … cm.

PRECAUTIONS

1. The screw may have friction.
2. Spherometer may have backlash error.

SOURCES OF ERROR

1. Parallax error while reading the pitch scale corresponding to the level of the circular scale.
2. Backlash error of the spherometer.
3. Non-uniformity of the divisions in the circular scale.
4. While setting the spherometer, screw may or may not be touching the horizontal plane surface or the spherical surface.

DISCUSSION

Does a given object, say concave mirror or a convex mirror, have the same radius of curvature for its two surfaces? [**Hint:** Does the thickness of the material of object make any difference?]

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Determine the focal length of a convex/concave spherical mirror using a spherometer.
2. (a) Using spherometer measure the thickness of a small piece of thin sheet of metal/glass.

   (b) Which instrument would be precise for measuring thickness of a card sheet – a screw gauge or a spherometer?