Determine the volume of a sphere using micrometer (screw gauge)

The most widely used device for the accurate measurement of small dimensions is the micrometer (screw gauge), as shown below. It is particularly convenient in measuring the diameters of thin wires and the thicknesses of thin sheets.

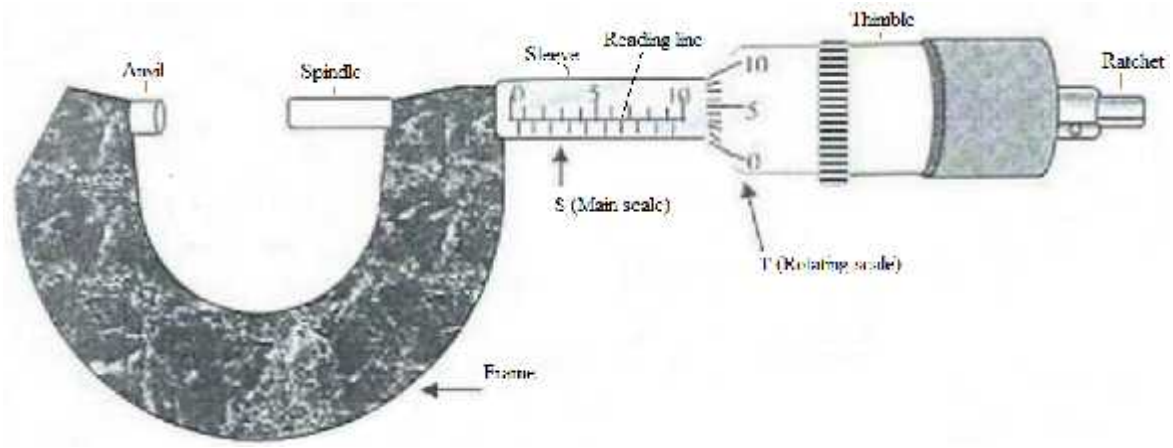

Figure 1. Micrometer

- The axial line on the sleeve main scale serves as a reading line.
- The movement mechanism of the micrometer is a carefully machined screw with a pitch of 0.5 mm. The pitch of a screw, or the distance between screw threads, is the lateral linear distance the screw moves when turned through one rotation.
- One complete turn of T (rotating scale) is $0.5\ mm$ on main scale and the numbers on the S (main scale) show the number of millimeters. Since there are 50 divisions on the T (rotating scale). Lengths can be measured to hundredth's of a millimeter.

$$Least\ count\ (L.C) = \frac{pitch\ of\ the\ screw}{total\ number\ of\ divisions\ on\ the\ rotating\ scale} = \frac{0.5}{50} = 0.01 mm$$

Example of a micrometer reading:

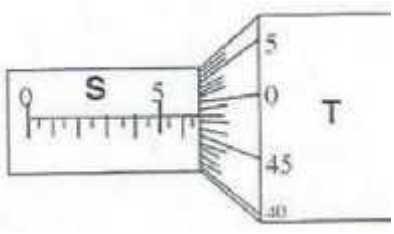

Figure 2. Micrometer reading

The S (main scale) reading $= 6.5\ mm.$

Number of rotating scale divisions coinciding with the reading line $= 48.$

Least count $= 0.01\ mm$

Rotating scale reading $48 \times 0.01 = 0.48\ mm$

The complete reading $= 6.5 + 0.48 = 6.98\ mm$

Volume of a sphere

$$V = \frac{4}{3}\text{®}r^3$$, where r is the radius of the sphere

Diameter of the sphere:

Main scale reading $a\,(mm)$	Number of rotating scale divisions coinciding with the reading line n	Rotating scale reading $b = n \times least\ count\ (mm)$	Total reading $d = a + b\ \ (mm)$

Diameter of the sphere = d = (mm)

Radius of the sphere = r = (mm)

$$V = \frac{4}{3}\text{®}r^3$$

Volume in $V =$ mm^3

Volume in $V =$ cm^3

Use: $\pm_r = \pm 0.005\,mm$ (reading error)

Standard deviation (error propagation)

$$\pm_V = V\left[\left(\frac{3}{r}\right)^2 \cdot \pm_r{}^2\right]^{1/2} = V\left(\frac{3}{r} \times \pm_r\right)$$

$$\therefore Volume = V \pm \pm_V =$$

Precautions and care

- Clean the ends of the anvil and spindle before use.
- Check the instrument for zero error (systematic error) reading before use.
- While taking measurements, the thimble is turned until the object is gripped very gently between anvil and spindle.
- Use the ratchet to apply a consistent pressure on the object. The ratchet permits the jaw to be tightened on an object with the same amount of force each time.

Zero error.

- If on touching the tip of the spindle with the anvil, the zero mark of the rotating scale coincides with the zero mark of the reading line, the instrument is free from zero error, figure 3 (a).
- But if the zero mark of the rotating scale remains below the reading line of the main scale, the zero error is said to be positive. **To find it**, note the division of the rotating scale which coincides with the reading line of the main scale. Now multiply this number with the least count which gives the zero error. In figure 3(b) the 2 division of rotating scale coincides with the reading line. If the least count of the screw gauge is 0.01 mm, then zero error is $= +2 \times 0.01 = +0.02\, mm.$
- On the other hand, if the zero of the rotating scale goes above the reading line of the main scale, the zero error is said to be negative. **To find it**, note the division of the rotating scale which coincides with the reading line of the main scale. Subtract it from the total number of divisions on the rotating scale and then multiply it with the least count. In figure 3(c) 46 division of rotating scale coincides with the reading line and the total number of divisions on the rotating scale are 50 and the least count is 0.01 mm, then the zero error $= -(50 - 46) \times 0.01 = -0.04\, mm.$
- To find the correct reading, the zero error with its proper signs is subtracted from the observed reading. Thus,

Correct reading = observed reading – zero error (with sign)

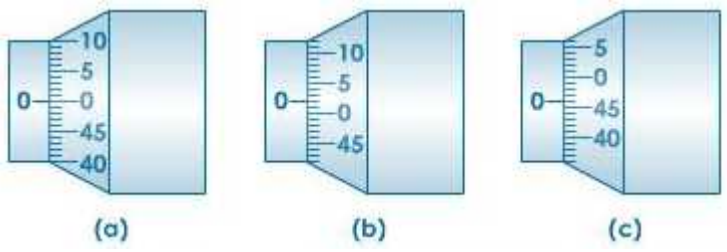

Figure 3. (a) No zero error (b) Positive zero error (c) Negative zero error