EXPERIMENT 1

AIM

Use of Vernier Callipers to

(i) measure diameter of a small spherical/cylindrical body,

(ii) measure the dimensions of a given regular body of known mass and hence to determine its density; and

(iii) measure the internal diameter and depth of a given cylindrical object like beaker/glass/calorimeter and hence to calculate its volume.

APPARATUS AND MATERIAL REQUIRED

Vernier Callipers, Spherical body, such as a pendulum bob or a glass marble, rectangular block of known mass and cylindrical object like a beaker/glass/calorimeter

DESCRIPTION OF THE MEASURING DEVICE

1. A Vernier Calliper has two scales–one main scale and a Vernier scale, which slides along the main scale. The main scale and Vernier scale are divided into small divisions though of different magnitudes.

The main scale is graduated in cm and mm. It has two fixed jaws, A and C, projected at right angles to the scale. The sliding Vernier scale has jaws (B, D) projecting at right angles to it and also the main scale and a metallic strip (N). The zero of main scale and Vernier scale coincide when the jaws are made to touch each other. The jaws and metallic strip are designed to measure the distance/diameter of objects. Knob P is used to slide the vernier scale on the main scale. Screw S is used to fix the vernier scale at a desired position.

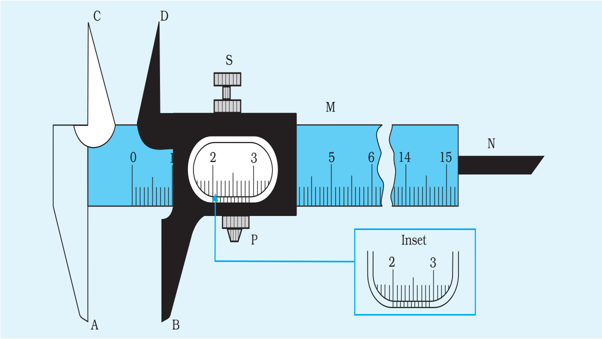

Fig. E 1.1 *Vernier Calliper*

2. The least count of a common scale is 1mm. It is difficult to further subdivide it to improve the least count of the scale. A vernier scale enables this to be achieved.

PRINCIPLE

The difference in the magnitude of one main scale division (M.S.D.) and one vernier scale division (V.S.D.) is called the least count of the instrument, as it is the smallest distance that can be measured using the instrument.

$$n \text{ V.S.D.} = (n - 1) \text{ M.S.D.}$$

Formulas Used

(a) Least count of vernier callipers

$$= \frac{\textit{the magnitude of the smallest division on the main scale}}{\textit{the total number of small divisions on the vernier scale}}$$

(b) Density of a rectangular body = $\frac{mass}{volume} = \frac{m}{V} = \frac{m}{l.b.h}$ where m is its mass, l its length, b its breadth and h the height.

(c) The volume of a cylindrical (hollow) object $V = \pi r^2 h' = \frac{\pi D'^2}{4}.h'$ where h' is its internal depth, D' is its internal diameter and r is its internal radius.

PROCEDURE

(a) Measuring the diameter of a small spherical or cylindrical body.

1. Keep the jaws of Vernier Callipers closed. Observe the zero mark of the main scale. It must perfectly coincide with that of the vernier scale. If this is not so, account for the zero error for all observations to be made while using the instrument as explained on pages 26-27.
2. Look for the division on the vernier scale that coincides with a division of main scale. Use a magnifying glass, if available and note the number of division on the Vernier scale that coincides with the one on the main scale. Position your eye directly over the division mark so as to avoid any parallax error.
3. Gently loosen the screw to release the movable jaw. Slide it enough to hold the sphere/cylindrical body gently (without any undue pressure) in between the lower jaws AB. The jaws should be perfectly perpendicular to the diameter of the body. Now, gently tighten the screw so as to clamp the instrument in this position to the body.
4. Carefully note the position of the zero mark of the vernier scale against the main scale. Usually, it will not perfectly coincide with

any of the small divisions on the main scale. Record the main scale division just to the left of the zero mark of the vernier scale.

5. Start looking for exact coincidence of a vernier scale division with that of a main scale division in the vernier window from left end (zero) to the right. Note its number (say) N, carefully.

6. Multiply 'N' by least count of the instrument and add the product to the main scale reading noted in step 4. Ensure that the product is converted into proper units (usually cm) for addition to be valid.

7. Repeat steps 3-6 to obtain the diameter of the body at different positions on its curved surface. Take three sets of reading in each case.

8. Record the observations in the tabular form [Table E 1.1(a)] with proper units. Apply zero correction, if need be.

9. Find the arithmetic mean of the corrected readings of the diameter of the body. Express the results in suitable units with appropriate number of significant figures.

(b) Measuring the dimensions of a regular rectangular body to determine its density.

1. Measure the length of the rectangular block (if beyond the limits of the extended jaws of Vernier Callipers) using a suitable ruler. Otherwise repeat steps 3-6 described in (a) after holding the block lengthwise between the jaws of the Vernier Callipers.

2. Repeat steps 3-6 stated in (a) to determine the other dimensions (breadth b and height h) by holding the rectangular block in proper positions.

3. Record the observations for length, breadth and height of the rectangular block in tabular form [Table E 1.1 (b)] with proper units and significant figures. Apply zero corrections wherever necessary.

4. Find out the arithmetic mean of readings taken for length, breadth and height separately.

[c] Measuring the internal diameter and depth of the given beaker (or similar cylindrical object) to find its internal volume.

1. Adjust the upper jaws CD of the Vernier Callipers so as to touch the wall of the beaker from inside without exerting undue pressure on it. Tighten the screw gently to keep the Vernier Callipers in this position.

2. Repeat the steps 3-6 as in (a) to obtain the value of internal diameter of the beaker/calorimeter. Do this for two different (angular) positions of the beaker.

3. Keep the edge of the main scale of Vernier Callipers, to determine the depth of the beaker, on its peripheral edge. This should be done in such a way that the tip of the strip is able to go freely inside the beaker along its depth.

4. Keep sliding the moving jaw of the Vernier Callipers until the strip just touches the bottom of the beaker. Take care that it does so while being perfectly perpendicular to the bottom surface. Now tighten the screw of the Vernier Callipers.

5. Repeat steps 4 to 6 of part (a) of the experiment to obtain depth of the given beaker. Take the readings for depth at different positions of the breaker.

6. Record the observations in tabular form [Table E 1.1 (c)] with proper units and significant figures. Apply zero corrections, if required.

7. Find out the mean of the corrected readings of the internal diameter and depth of the given beaker. Express the result in suitable units and proper significant figures.

OBSERVATIONS

(i) Least count of Vernier Callipers (Vernier Constant)

1 main scale division (MSD) = 1 mm = 0.1 cm

Number of vernier scale divisions, N = 10

10 vernier scale divisions = 9 main scale divisions

1 vernier scale division = 0.9 main scale division

Vernier constant = 1 main scale division – 1 vernier scale division

= (1– 0.9) main scale divisions

= 0.1 main scale division

Vernier constant (V_C) = 0.1 mm = 0.01 cm

Alternatively,

$$\text{Vernier constant} = \frac{1\text{MSD}}{\text{N}} = \frac{1 \text{ mm}}{10}$$

Vernier constant (V_C) = 0.1 mm = 0.01 cm

(ii) Zero error and its correction

When the jaws A and B touch each other, the zero of the Vernier should coincide with the zero of the main scale. If it is not so, the instrument is said to possess zero error (e). Zero error may be

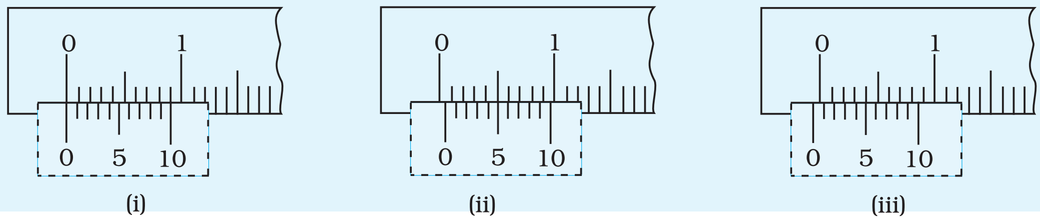

Fig. E 1.2: Zero error (i) no zero error (ii) positive zero error (iii) negative zero error

positive or negative, depending upon whether the zero of vernier scale lies to the right or to the left of the zero of the main scale. This is shown by the Fig. E1.2 (ii) and (iii). In this situation, a correction is required to the observed readings.

(iii) Positive zero error

Fig E 1.2 (ii) shows an example of positive zero error. From the figure, one can see that when both jaws are touching each other, zero of the vernier scale is shifted to the right of zero of the main scale (This might have happened due to manufacturing defect or due to rough handling). This situation makes it obvious that while taking measurements, the reading taken will be more than the actual reading. Hence, a correction needs to be applied which is proportional to the right shift of zero of vernier scale.

In ideal case, zero of vernier scale should coincide with zero of main scale. But in Fig. E 1.2 (ii), 5^{th} vernier division is coinciding with a main scale reading.

$\therefore$ Zero Error = + 5 × Least Count = + 0.05 cm

Hence, the zero error is positive in this case. For any measurements done, the zero error (+ 0.05 cm in this example) should be 'subtracted' from the observed reading.

$\therefore$ True Reading = Observed reading – (+ Zero error)

(iv) Negative zero error

Fig. E 1.2 (iii) shows an example of negative zero error. From this figure, one can see that when both the jaws are touching each other, zero of the vernier scale is shifted to the left of zero of the main scale. This situation makes it obvious that while taking measurements, the reading taken will be less than the actual reading. Hence, a correction needs to be applied which is proportional to the left shift of zero of vernier scale.

In Fig. E 1.2 (iii), 5^{th} vernier scale division is coinciding with a main scale reading.

$\therefore$ Zero Error = – 5 × Least Count

= – 0.05 cm

Note that the zero error in this case is considered to be negative. For any measurements done, the negative zero error, (–0.05 cm in this example) is also substracted 'from the observed reading', though it gets added to the observed value.

∴ True Reading = Observed Reading – (– Zero error)

Table E 1.1 (a): Measuring the diameter of a small spherical/ cylindrical body

S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, $V = N \times V_C$ (cm/mm)	Measured diameter, $M + V$ (cm/mm)
1				
2				
3				
4				

Zero error, e = ± ... cm

Mean observed diameter = ... cm

Corrected diameter = Mean observed diameter – Zero Error

Table E 1.1 (b) : Measuring dimensions of a given regular body (rectangular block)

Dimension	S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, $V = N \times V_C$ (cm/mm)	Measured dimension $M + V$ (cm/mm)
Length (l)	1				
	2				
	3				
Breadth (b)	1				
	2				
	3				
Height (h)	1				
	2				
	3				

Zero error = ± ... mm/cm

Mean observed length = ... cm, Mean observed breadth = ... cm

Mean observed height = ... cm

Corrected length = ... cm; Corrected breath = ... cm;

Corrected height = ...cm

Table E 1.1 (c) : Measuring internal diameter and depth of a given beaker/ calorimeter/ cylindrical glass

Dimension	S. No.	Main Scale reading, M (cm/mm)	Number of coinciding vernier division, N	Vernier scale reading, $V = N \times V_C$ (cm/mm)	Measured diameter depth, $M + V$ (cm/mm)
Internal diameter (D')	1 2 3				
Depth (h')	1 2 3				

Mean diameter = ... cm

Mean depth= ... cm

Corrected diameter = ... cm

Corrected depth = ... cm

CALCULATION

(a) Measurement of diameter of the sphere/ cylindrical body

Mean measured diameter, $D_o = \dfrac{D_1 + D_2 + ... + D_6}{6}$ cm

D_o = ... cm = ... × 10^{-2} m

Corrected diameter of the given body, D = D_o – (± e) = ... × 10^{-2} m

(b) Measurement of length, breadth and height of the rectangular block

Mean measured length, $l_o = \dfrac{l_1 + l_2 + l_3}{3}$ cm

l_o = ... cm = ... × 10^{-2} m

Corrected length of the block, $l = l_o - (\pm e)$ = ... cm

Mean observed breadth, $b_o = \dfrac{b_1 + b_2 + b_3}{3}$

Mean measured breadth of the block, b_0 = ... cm = ... × 10^{-2} m

Corrected breadth of the block,

$$b = b_O - (\pm e) \text{ cm} = ... \times 10^{-2} \text{ m}$$

Mean measured height of block $h_o = \frac{h_1 + h_2 + h_3}{3}$

Corrected height of block $h = h_o - (\pm e)$ = ... cm

Volume of the rectangular block,

$$V = lbh = \ldots \text{ cm}^3 = \ldots \times 10^{-6} \text{ m}^3$$

Density ρ of the block,

$$\rho = \frac{m}{V} = \ldots \text{ kgm}^{-3}$$

(c) Measurement of internal diameter of the beaker/glass

Mean measured internal diameter, $D_o = \frac{D_1 + D_2 + D_3}{3}$

$$D_o = \ldots \text{ cm} = \ldots \times 10^{-2} \text{ m}$$

Corrected internal diameter,

$$D = D_o - (\pm e) = \ldots \text{ cm} = \ldots \times 10^{-2} \text{ m}$$

Mean measured depth of the beaker, $h_o = \frac{h_1 + h_2 + h_3}{3}$

$$= \ldots \text{ cm} = \ldots \times 10^{-2} \text{ m}$$

Corrected measured depth of the beaker

$$\text{h} = h_o - (\pm e) \ldots \text{ cm} = \ldots \times 10^{-2} \text{ m}$$

Internal volume of the beaker

$$V = \frac{\pi \text{D}^2 \text{h}}{4} = \ldots \times 10^{-6} \text{ m}^3$$

RESULT

(a) Diameter of the spherical/ cylindrical body,

$$D = \ldots \times 10^{-2} \text{m}$$

(b) Density of the given rectangular block,

$$\rho = \ldots \text{ kgm}^{-3}$$

(c) Internal volume of the given beaker

$$V' = \ldots \text{ m}^3$$

PRECAUTIONS

1. If the vernier scale is not sliding smoothly over the main scale, apply machine oil/grease.
2. Screw the vernier tightly without exerting undue pressure to avoid any damage to the threads of the screw.
3. Keep the eye directly over the division mark to avoid any error due to parallax.
4. Note down each observation with correct significant figures and units.

SOURCES OF ERROR

Any measurement made using Vernier Callipers is likely to be incorrect if-

(i) the zero error in the instrument placed is not accounted for; and

(ii) the Vernier Callipers is not in a proper position with respect to the body, avoiding gaps or undue pressure or both.

DISCUSSION

1. A Vernier Callipers is necessary and suitable only for certain types of measurement where the required dimension of the object is freely accessible. It cannot be used in many situations. e.g. suppose a hole of diameter 'd' is to be drilled into a metal block. If the diameter *d* is small - say 2 mm, neither the diameter nor the depth of the hole can be measured with a Vernier Callipers.
2. It is also important to realise that use of Vernier Callipers for measuring length/width/thickness etc. is essential only when the desired degree of precision in the result (say determination of the volume of a wire) is high. It is meaningless to use it where precision in measurement is not going to affect the result much. For example, in a simple pendulum experiment, to measure the diameter of the bob, since $L >> d$.

SELF ASSESSMENT

1. One can undertake an exercise to know the level of skills developed in making measurements using Vernier Callipers. Objects, such as *bangles/kangan*, marbles whose dimensions can be measured indirectly using a thread can be used to judge the skill acquired through comparison of results obtained using both the methods.
2. How does a vernier decrease the least count of a scale.

SUGGESTED ADDITIONAL EXPERIMENTS/ACTIVITIES

1. Determine the density of glass/metal of a (given) cylindrical vessel.
2. Measure thickness of doors and boards.
3. Measure outer diameter of a water pipe.

ADDITIONAL EXERCISE

1. In the vernier scale normally used in a Fortin's barometer, 20 VSD coincide with 19 MSD (each division of length 1 mm). Find the least count of the vernier.
2. In vernier scale (angular) normally provided in spectrometers/sextant, 60 VSD coincide with 59 MSD (each division of angle 1°). Find the least count of the vernier.
3. How would the precision of the measurement by Vernier Callipers be affected by increasing the number of divisions on its vernier scale?
4. How can you find the value of π using a given cylinder and a pair of Vernier Callipers?

   [**Hint** : Using the Vernier Callipers, - Measure the diameter *D* and find the circumference of the cylinder using a thread. Ratio of circumference to the diameter (*D*) gives π.]
5. How can you find the thickness of the sheet used for making of a steel tumbler using Vernier Callipers?

   [**Hint:** Measure the internal diameter (D_i) and external diameter (D_o) of the tumbler. Then, thickness of the sheet $D_t = (D_o - D_i)/2$.]