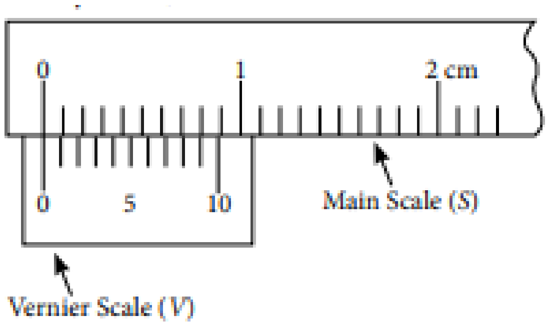
Experiment - 1 : Vernier Callipers-Its use to measure the internal and external diameter and depth of a vessel.

It was designed by the French Mathematician Pierre Vernier, and hence the instrument is called vernier callipers.

The callipers have two scales namely the main scale and vernier scale. The main scale is fixed but the vernier (also called auxiliary scale) is moveable.



The divisions on the vernier scale are slightly smaller than the smaller divisions on the main scale. Its operation is based on an ingenious principle as follows:

Principle

Let the size of a main scale division be S units and that of a vernier scale be V units. Also, suppose the n divisions of vernier scale coincide with (n – 1) divisions of the main scale. Then

$(n - 1) \cdot S = n \cdot V$ or $nS - S = nV$

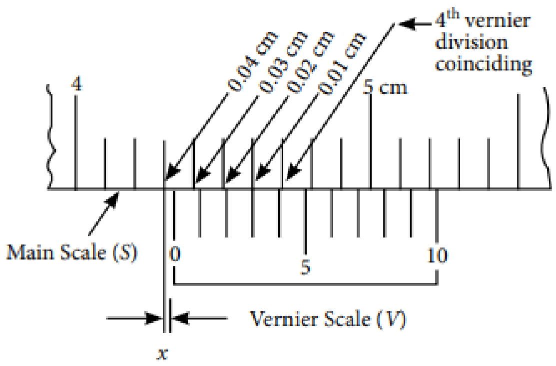
$$(S - V) = \frac{\text{Size of the smallest main scale division}}{\text{The total number of division on the vernier scale}}$$

(S – V) is called the vernier constant and happens to be its 'least count' or the smallest value of a physical quantity which can be measured with this instrument. Usually in a 'Vernier Callipers' n = 10, so its least count is

$$(S - V) = \left(\frac{1\text{ mm}}{10}\right) = 0.1\text{ mm}$$

Vernier constant (V.C.) = 0.1 mm

How to Read a Vernier ? Let us take a case where while reading the length of an object, the zero of the vernier scale is positioned as shown.



As it can be noted, the length of the object is somewhere between 4.3 cm and 4.4 cm. Now the 'x' has to be measured. It is seen that the 4th division of vernier scale coincides with the division on the main scale. So,

4.3 cm + x + 4 vernier divisions = 4.3 cm + 4 main scale divisions

⇒ x = 4 main scale divisions – 4 vernier scale divisions

= 4 (S – V) = 4(0.1 mm) = 4(0.01 cm) = 0.04 cm

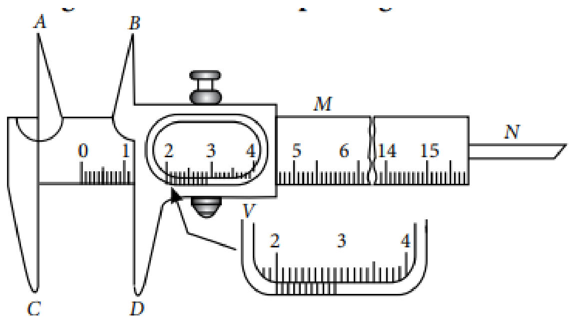
Thus the length of the object is

(4.3 cm + 0.04 cm) = 4.34 cm

Simply put, "the number of the vernier division exactly coinciding with the main scale division is multiplied by V.C. for the vernier reading. This then is added to the main scale reading.

Total Reading = (Main scale reading) + (Number of the vernier division coinciding) (V.C.)

The diagram of vernier callipers is given below



It can be described as a composite of the main scale, vernier scale, jaws and the strip.

(a) Main scale consists of a steel metallic strip at one end and carries fixed jaws AC at the other. The steel body of the main scale is graduated in mm or cm on one side and in inches on the other.

(b) Vernier scale V slides on the main scale M. It can be fixed at any position by screw S. The vernier scale has 10 divisions coinciding with the 9 smaller main scale divisions or 9 mm, on the cm side of the scale.

(c) Moveable jaws BD are carried by the vernier scale which project at right angles to the main scale. The other jaw AC is attached to the zero end of the vernier callipers and is also at right angles to the main scale. When vernier scale is pushed towards A and C, then as D touches C, the straight side of B will touch the straight side of A. In this position, if the instrument is free of zero errors, the zeroes of the vernier scale will coincide with the zero of the main scales on both the cm and inch scales.

The upper ends A and B are used to measure the internal dimensions of hollow objects (say, internal diameter of a cylindrical vessel). The lower ends C and D are used to measure the lengths and diameters of objects that are gripped between them (say, the external diameter of a cylindrical vessel).

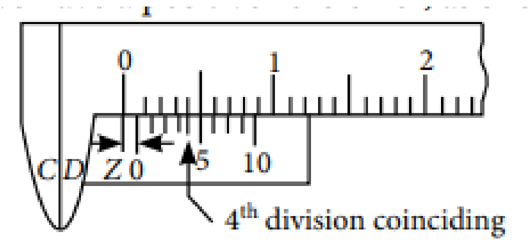
(d) Strip N is attached to the back side of the main scale and connected with the vernier scale. When jaws C and D touch each other, the edge of the strip N touches the edge of M. When the jaws C and D are separated, N moves outwards. The strip is used to measure the depth of a vessel.

Zero Error

Due to wear and tear of jaws due to prolonged use or some manufacturing defect, the zero marks of the main scale and vernier scale may not be in the same straight line, when the jaws are made to touch each other. This gives rise to an error called the zero-error.

Positive zero error and its correction.

If the zero of the vernier scale is to the right of the zero of the main scale, we have a positive zero error, as shown above.



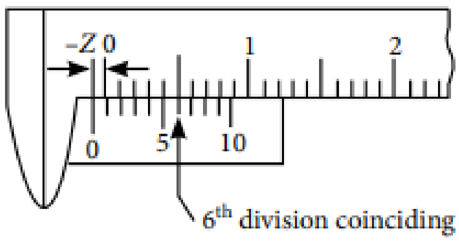
As can be seen, we read to measure Z the zero error, the gap between the main scale 0 and vernier scale 0. Here the 4^{th} division of the vernier scale (V) coincides with the 4^{th} division of the main scale (S).

$\Rightarrow Z + 4V = 4S$ or $Z = 4(S - V)$, $Z = 4(V \cdot C) = 4(0.1 \text{ mm}) = 0.4 \text{ mm}$

Positive zero error = (No. of the vernier division coinciding with main scale) × (V·C)

Negative zero error and its correction

If the zero of the vernier scale is to the left of the zero of the main scale, we have a negative zero error, as shown below



We again need to measure the gap between the main scale 0 and the vernier scale 0.

The gap is marked '–Z'. As Z is negative, so –Z will be positive. Here the 6th division of the vernier scale coincides with the 5th division of the main scale.

$\Rightarrow -Z + 5S = 6V$ Z

$= 5S - 6V = 6(S - V) - S = 6(0.1 \text{ mm}) - 1 \text{ mm} = -0.4 \text{ mm}$

Negative zero error = (No. of the vernier division coinciding with main scale) × (V.C.) – (smallest main scale unit)

Corrected reading = Observed reading – Zero with proper sign Sometimes, a term called zero correction is used. Zero correction is negative of the zero error. Zero correction is added to the observed reading to get the corrected reading.

Zero correction = – Zero error Corrected reading

= Observed reading + Zero correction

MCQs Corner

Experiment – 1

1. In an experiment the angles are required to be measured using an instrument. 29 divisions of the main scale exactly coincide with the 30 divisions of the vernier scale. If the smallest division of the main scale is half-a-degree (= 0.5°), then the least count of the instrument is

(a) one minute

(b) half minute

(c) one degree

(d) half degree

2. Diameter of a steel ball is measured using a Vernier calliper which has divisions of 0.1 cm on its main scale (MS) and 10 divisions of its vernier scale (VS) match 9 divisions on the main scale. Three such measurements for a ball are given as :

S.No.	MS (cm)	VS divisions
1	0.5	8
2.	0.5	4
3.	0.5	6

If the zero error is –0.03 cm, then mean corrected diameter is

(a) 0.56 cm

(b) 0.59 cm

(c) 0.53 cm

(d) 0.52 cm

3. When the jaws of a standard vernier are together, the 6th vernier scale division coincides with the 6th main scale division, then the zero error is

(a) + 0.4 mm

(b) –0.4 mm

(c) + 0.6 mm

(d) –0.6 mm

4. In an unusual vernier, 10 vernier scale divisions, coincide with 8 main scale divisions, then the least count of the vernier is

(a) $\frac{1}{8}$ mm

(b) 0.1 mm

(c) 0.2 mm

(d) 0.8 mm

5. The Vernier constant of Vernier callipers is 0.1 mm and it has zero error of –0.05 cm. While measuring diameter of a sphere, the main scale reading is 1.7 cm and coinciding vernier division is 5. The corrected diameter will be

(a) 1.8 cm

(b) 2.8 cm

(c) 2.3 cm

(d) 1.5 cm

6. In a vernier callipers, each cm on the main scale is divided into 20 equal parts. If tenth vernier scale division coincides with ninth main scale division. Then the value of vernier constant is

(a) 2×10^{-2} mm

(b) 2×10^{-1}mm

(c) 5×10^{-1} mm

(d) 5×10^{-2} mm

Answer Key

1. (a) 2. (b) 3. (c) 4. (c) 5. (a) 6. (d)

Hints & Explanation

1. **(a) :** Least count $= \dfrac{\text{value of 1 main scale division}}{\text{number of divisions on the vernier scale}}$

as shown below.
Here n vernier scale divisions = $(n-1)$ M.S.D.

$$\therefore\ 1\,\text{V.S.D.} = \frac{n-1}{n}\,\text{M.S.D}$$

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

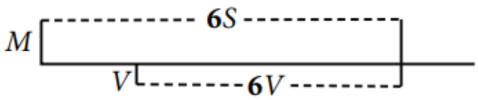
$$\Rightarrow\ \text{L.C.} = 0.5^\circ - \frac{29}{30}\times 0.5^\circ$$

$$\Rightarrow\ \text{L.C.} = \frac{0.5}{30} = \frac{1}{30}\times\frac{1}{2} = \left(\frac{1}{60}\right)^\circ = 1\,\text{min}$$

2. **(b) :** Least count = 0.01 cm
$d_1 = 0.5 + 8 \times 0.01 + 0.03 = 0.61$ cm
$d_2 = 0.5 + 4 \times 0.01 + 0.03 = 0.57$ cm
$d_3 = 0.5 + 6 \times 0.01 + 0.03 = 0.59$ cm
Mean diameter,

$$\bar{d} = \frac{d_1 + d_2 + d_3}{3} = \frac{0.61 + 0.57 + 0.59}{3} = 0.59\ \text{cm}$$

3. **(c) :** As vernier divisions are smaller than the main scale divisions ($9S = 10V$), the zero of the vernier must be on the right side of the zero of the main scale. Here zero error is positive.



$\Rightarrow$ Zero error $= 6S - 6V = 6(S - V) = 6(0.1\text{ mm}) = +\,0.6$ mm

4. **(c) :** $8S = 10V \Rightarrow 10S - 2S = 10V,\ 10(S - V) = 2S,$

$$(S - V) = \frac{2S}{10} = 0.2\ \text{mm.}$$

5. **(a) :** Given, LC = 0.1 mm, zero error = – 0.05 cm
MSR = 1.7 cm, $n = 5$
So, VSR = 5 × LC = 5 × 0.1 = 0.5 mm = 0.05 cm
Diameter = MSR + VSR – zero error
= 1.7 + 0.05 – (–0.05) = 1.8 cm

6. **(d) :** 1 cm is divided into 20 divisions

$1\,\text{MSD} = \frac{1}{20}\,\text{cm}$; 10 VSD = 9 MSD; $1\,\text{VSD} = \frac{9}{10}\,\text{MSD}$

$\text{LC} = 1\,\text{MSD} - 1\,\text{VSD} = 1\,\text{MSD} - \frac{9}{10}\,\text{MSD}$

$\text{LC} = \frac{1}{10}\,\text{MSD} = \frac{1}{10} \times \frac{1}{20}\,\text{cm} = \frac{1}{200}\,\text{cm}$

$\text{LC} = \frac{1}{200} \times 10\,\text{mm} = \frac{1}{200} \times \frac{10^2}{10^2} \Rightarrow \text{LC} = 5 \times 10^{-2}\,\text{mm}$