Physics is an exact science or the science of measurements, concerned with the nature and properties of matter and energy.

For progress in science and technology, reliable and **accurate measurements** are required to meet our day-to-day requirements.

Measurement is the determination of the magnitude of any physical quantity in terms of a standard or a unit.

Measurement is a comparison between an unknown quantity (to be measured) and a known quantity (called **a standard** or **a unit**).

Unit is an internationally accepted reference standard to measure a physical quantity.

Result of a measurement of a physical quantity is expressed by a number or a numerical measure accompanied by a unit. Thus,

Measurement of any physical quantity (Q) = numerical measure (n) × unit (u)

In any measurement, numerical measure (n) is **inversely proportional** to the size of the unit selected *i.e.*,

$$n \propto \frac{1}{u} \quad \text{or} \quad n_1 u_1 = n_2 u_2$$

Physical quantities in physics are the quantities which can be measured directly or indirectly.

Fundamental quantities are those quantities which are independent of one another, *e.g.*, length, mass, time, current, temperature, amount of substance, luminous intensity, plane angle and solid angle.

Derived quantities are those quantities which are derived from two or more fundamental quantities, *viz.*, speed, acceleration, work, pressure, etc.

To measure fundamental quantities and derived quantities respectively fundamental (or base) units and derived units are required. **Fundamental unit** or **base unit** is an independent unit which can neither be derived from one another nor can be further resolved into simple unit of any other physical quantity.

Derived unit can be obtained from the fundamental or base units.

Essential properties of a unit are that it must be

(*i*) invariable
(*ii*) easily accessible
(*iii*) easily reproducible
(*iv*) well-defined
(*v*) imperishable.

In **British system (FPS system) of units,** the units of length, mass and time are respectively foot, pound and second.

In **French system (CGS system),** the units of length, mass and time are respectively centimetre, gram and second.

In **MKS and MKSA system,** the units of length, mass and time are respectively metre, kilogram and second and ampere is the base unit of current.

At present the International system of units or SI (abbreviated form of the French name Le System Internationale *d'* unites) is used **universally** for measurement. The list of all the seven fundamental or base quantities with their units and symbols are shown in the following table :

International System of Units (SI) of the fundamental quantities.

S. No.	*Physical Quantity*	*Units*	
	Fundamental Quantities	***Name***	***Symbol***
1.	Length	metre	m
2.	Mass	kilogram	kg
3.	Time	second	s
4.	Temperature	kelvin	K
5.	Electric current	ampere	A
6.	Luminous intensity	candela	cd
7.	Amount of substance	mole	mol
	Supplementary units		
1	Angle	radian	rad
2.	Solid angle	steradian	sr

Least count is the least measurement that can be done by any instrument accurately.

Following instruments are used for measuring lengths, *e.g.*, (*i*) ruler, (*ii*) callipers, (*iii*) vernier callipers and (*iv*) screw gauge.

In daily life, the length is measured by the help of a **metre scale.** It is graduated to read up to one mm.

While taking measurements following precautions should be observed :

(*i*) Measure the length from the graduation other than the end marked 'O' to avoid error due to wear and tear of this end. Then the correct length will be the difference of the markings observed at two ends.

(*ii*) To avoid parallax error due to the thickness of the scale, the eye must be kept vertically above the end of the object and the corresponding graduation in the line of sight.

In seventeenth century French mathematician, Pierre Vernier devised a method **to measure a length**

correctly up to 0.1 mm. In this method there are two scales ; one scale called the **main scale** is fixed and graduated in millimetre and the other scale called the **vernier scale** which slides along the main scale.

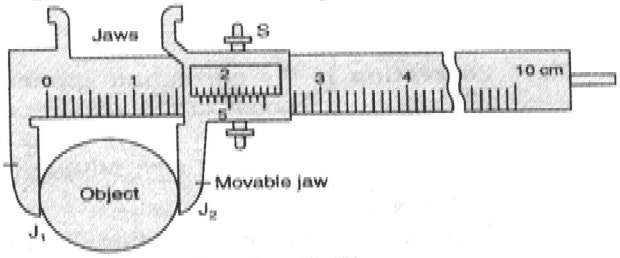
According to the principle of vernier callipers

length of n divisions on vernier scale = length of $(n-1)$ divisions of the main scale.

Vernier constant is equal to the difference between the values of one main scale division(s) and one vernier scale division (V).

Least count of vernier is the least distance which can be measured accurately by it. It is also equal to vernier constant.

Vernier callipers is also called **slide callipers.** It is used to measure the length of a rod, depth of a small beaker, diameter of a sphere, the internal and external diameters of a hollow cylinder.

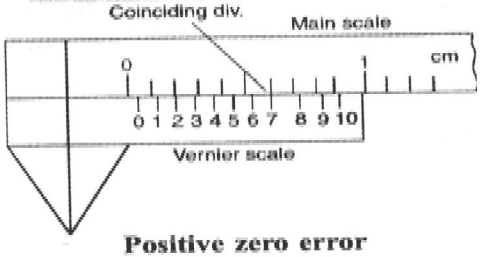


Vernier Callipers

On bringing the movable jaw of contact with the fixed jaw, if the zero of the main scale coincides with the zero of the vernier scale, then the given vernier is free from zero error. But if zero of the vernier scale does not coincide with the zero of the main scale, the vernier is said to have zero error. It is equal to the distance between the zero of the main scale and the zero of the vernier scale. Zero error is of two kinds *viz,* **positive zero error** and **negative zero error. The zero error is said to be positive** if on bringing both the jaws together, the zero mark of the vernier is on the right hand side of the zero mark of the main scale.

Positive zero error is equal to the number of the vernier division x (coinciding with any division on the main scale) multiplied with the least count (LC) of vernier.

Positive zero error = $+ x \times$ LC

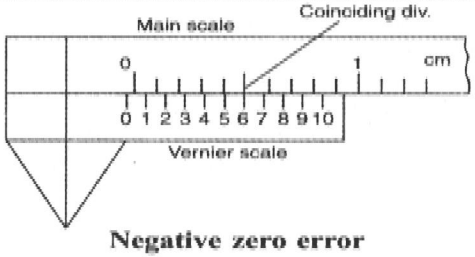


Positive zero error

The zero error is said to be negative, if on bringing both the jaws together, the zero mark of the vernier is on the left side of the zero of the main scale.

Negative zero error is equal to the difference (of the coinciding vernier scale division x from the total number of divisions on the vernier scale) multiplied by the least count, *e.g.,*

Negative zero error = $-(n-x) \times$ LC.



Negative zero error

Zero correction is the correction applied to a measured value on account of the zero error. It is negative of the zero error, *i.e.,* it is negative for positive zero error and positive for negative zero error. Hence the corrected reading :

Corrected reading = observed reading − zero error with sign of a micrometer screw gauge.

Pitch of a micrometer screw gauge is the distance traversed by the screw (or the spindle) in one complete rotation of its head (or thimble) or the distance between its two consecutive threads.

Circular or **head scale** is the number of divisions graduated along the circumference of the screw head.

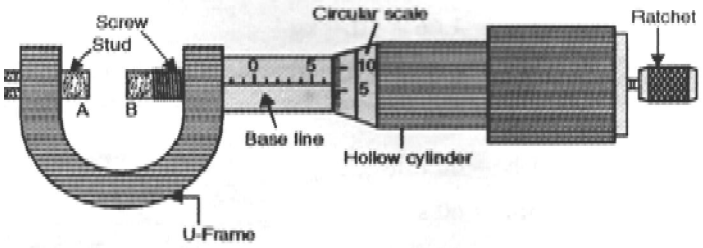
Least count of a micrometer screw gauge is the ratio of pitch to the total number of divisions on the circular scale, *i.e.,*

$$\text{Least Count (L.C.)} = \frac{\text{Pitch of the screw}}{\text{Total number of divisions on the circular scale}}$$

Back-lash error is the error due to wear and tear of the threads of the screw due to which on reversing the direction of rotation of the thimble, the tip of the screw does not move in the opposite direction immediately but remains stationary for a part of rotation.

On completely closing the gap between the spindle and the anvil by turning the thimble, if the zero mark on the main scale exactly coincides with the zero of the circular scale, the instrument is said to be **free**

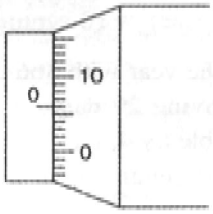
from the zero error. If it does not coincides, the instrument has zero error.



Screw Gauge

The zero error is said to be positive if the zero mark on the circular scale is below the base line of the main scale. It is equal to the number of circular scale division (x) coinciding with the base line multiplied with the least count of the screw gauge, *i.e.*,

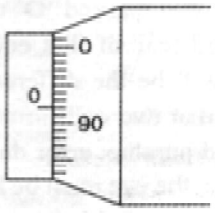
$$\text{Positive zero error} = +x \times \text{L.C.}$$



Positive zero error

The zero error is said to be negative, if the zero mark on the circular scale is above the base line of the main scale. It is equal to the multiplication of the difference of the number of the coinciding circular scale division (x) with the base line from the total number of divisions (n) on the circular scale with the least count, *i.e.*,

$$\text{Negative zero error} = -(n - x) \times \text{LC.}$$



Negative zero error

To get the correct reading, the zero error with its sign is subtracted from the observed reading, *i.e.*,

The period of oscillation (T) is

(i) directly proportional to the square root of its length (l), *i.e.*, $T \propto \sqrt{l}$.

(ii) inversely proportional to the square root of acceleration due to gravity (g), *i.e.*, $T \propto \frac{1}{\sqrt{g}}$

Thus, $T = 2\pi\sqrt{\frac{l}{g}}$.

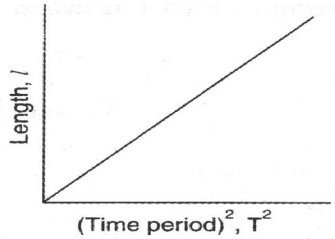
The period of oscillation does not depend on

(i) mass of the material and shape of the bob, and

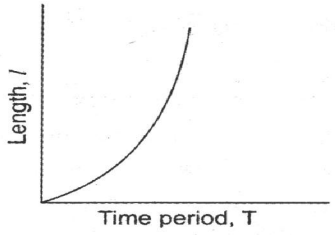
(ii) amplitude of oscillation.

Second's pendulum is that pendulum whose time period is 2 s.

(i) Graph l versus T^2 is a straight line.



(ii) Graph l versus T is a curve.



IMPORTANT QUESTIONS

Q1. What do you mean by measurement ?

Ans. Measurement is the comparison of an unknown quantity with a known quantity.

Q2. What do you mean by a unit ?

Ans. Unit is an internationally accepted reference standard to measure a physical quantity.

Q3. How will you express the result of a measurement of a physical quantity ?

Ans. Result of a measurement of a physical quantity is expressed by a number of numerical measure accompanied by a unit.

Thus, measurement of a physical quantity (Q) = numerical measure (n) × unit (u).

Q4. How is numerical measure of a physical quantity related to a unit ?

Ans. The numerical measure (n) of a physical quantity is inversely proportional to its unit (u), *i.e.*, $n \propto \frac{1}{u}$ or the product of numerical value and the unit is always a constant, *e.g.*, if n_1 and n_2 are the numerical measures of a physical quantity in two different units u_1 and u_2,

$$n_1u_1 = n_2u_2$$

Q5. What do you understand by a physical quantity ?

Ans. Physical quantity in physics is the quantity which can be measured directly or indirectly.

Q6. What do you mean by 'Le System Internationale *d*' unites ?

Ans. At present 'Le System Internationale *d*' unites is an internationally accepted system of units for measurement whose Indian equivalent is International System of units abbreviated as SI. In SI, there are seven fundamental units and two supplementary units given in Table on page 12.

Q7. What are the advantages of International System of units over other systems ?

Ans. The International System of units (SI) has following advantages over other systems :

(*i*) It is a rational system, *i.e.*, only one unit for one physical quantity like joule is the unit of energies of different types of mechanical energy, heat energy, electrical energy, etc.

(*ii*) It is a coherent system, *i.e.*, all derived units can be obtained by simple multiplication or division of the fundamental units without introducing any numerical factor.

Q8. Define 1 kilogram on an atomic scale.

Ans. On atomic scale, 1 kilogram is equivalent to the mass of 5.0188×10^{25} atoms of carbon isotope $^{12}_{6}C$.

Q9. What do you mean by the following terms :
(*i*) least count of an instrument
(*ii*) vernier constant ?

Ans. (*i*) Least count of an instrument means the least measurement (*e.g.* distance) which can be measured by this instrument accurately.

(*ii*) Vernier constant is equal to the difference between the values of one main scale division and one vernier scale division.

Q10. Is there any relationship between vernier constant and least count of vernier callipers ?

Ans. Yes. Vernier constant is numerically equal to the least count of vernier callipers.

Q11. Who invented vernier callipers ?

Ans. A Frenchman Pierre Vernier around 1600 AD invented the length measuring instrument vernier callipers.

Q12. What is the principle of vernier callipers ?

Ans. If the length of one vernier scale division is V and main scale division is s.

Length of n vernier scale divisions = length of $(n-1)$ divisions of main scale.

i.e., $nV = (n-1)\,s = ns - s$

$\therefore\ (s - V) = \frac{s}{n}$

Vernier constant

$$= \frac{\text{Length of one main scale division}}{\text{Total no. of divisions on vernier scale}}$$

Q13. What do you mean by zero correction ?

Ans. **Zero correction** is the correction applied to a measured value on account of the zero error. It is negative of the zero error, *i.e.*, it is negative for positive zero error and positive for negative zero error.

Corrected reading = observed reading − zero error with proper sign

Q14. State two characteristics of a true balance.

Ans. **Characteristics of a true balance :**

1. Both arms of the physical balance must be of equal lengths.
2. Both pans of the physical balance must be of equal masses.

Q15. Mention the relation between frequency and time period of a simple pendulum.

Ans. Frequency of a simple pendulum (ν) is equal to reciprocal of its time period (T), *i.e.*, $\nu \propto \frac{1}{T}$.

Q16. State the parameters on which time period of a simple pendulum does not depend.

Ans. **The period of oscillation does not depend on**

1. mass of the material and shape of the bob
2. amplitude of oscillation.

Q17. What will be the frequency of oscillation of a simple pendulum in a cabin that is falling freely under acceleration due to gravity ?

Ans. If a cabin is falling freely, acceleration due to gravity $g = 0$

$$\nu = \frac{1}{2\pi}\sqrt{\frac{g}{l}}$$

$\therefore\ \nu = 0$

NUMERICALS

Calculate the length of a second's pendulum at a place where acceleration due to gravtiy is 9.8 m/s².

Given, $T = 2$ s $g = 9.8$ m/s² $l = ?$

We know that $l = \frac{gT^2}{4\pi^2}$

$= \frac{(9.8 \text{ m/s}^2) \times (2 \text{ s})^2}{4 \times \left(\frac{22}{7}\right)^2} = 0.992$ m.

Compare the time periods of two pendulums of length 9 m and 1 m.

Given, $l_1 = 9$ m, $l_2 = 1$ m

We know that $T \propto \sqrt{l}$

$\therefore \quad \frac{T_1}{T_2} = \sqrt{\frac{l_1}{l_2}} = \sqrt{\frac{9 \text{ m}}{1 \text{ m}}} = \frac{3}{1}$

$\therefore \quad T_1 : T_2 = 3 : 1.$

How many protons would make 1 g if the mass of a proton is 1.67×10^{-27} kg ?

Number of protons in 1 g $= \frac{\text{total mass}}{\text{mass of one proton}}$

$= \frac{1 \text{ g}}{1.67 \times 10^{-27} \text{ kg}}$

$= \frac{1 \text{ g}}{(1.67 \times 10^{-27} \times 10^3) \text{ g}}$

$= 5.99 \times 10^{23}.$

What is the difference between angstrom unit and an astronomical unit ?

1 Å $= 10^{-10}$ m 1 AU $= 1.496 \times 10^{11}$ m

Express 0.01 mm in fermi.

We know that, 1 f $= 10^{-15}$ m or 1 m $= 10^{15}$ f

0.01 mm $= 0.01 \times 10^{-3}$ m $= 1 \times 10^{-5}$ m $= 10^{10}$ f.

How many electrons would make 1 kg if the mass of an electron is 9.1×10^{-31} kg ?

The number of electrons in 1 kg

$= \frac{\text{total mass}}{\text{mass of one electron}}$

$= \frac{1 \text{ kg}}{9.1 \times 10^{-31} \text{ kg}} = 1.1 \times 10^{30}.$

How much longer is a millimetre (mm) than a nanometre (nm) ?

1 mm $= 10^{-3}$ m, 1 nm $= 10^{-9}$ m

Ratio of 1 mm to 1 nm $= \frac{10^{-3} \text{ m}}{10^{-9} \text{ m}} = 10^6$

Calculate the quintals in a gigagram.

1 q = 100 kg 1 Gg $= 10^9$ g $= 10^6$ kg

Quintals in a gigagram $= \frac{1 \text{ Gg}}{1 \text{ q}} = \frac{10^6 \text{ kg}}{10^2 \text{ kg}} = 10^4.$

Calculate the number of seconds in 365 days.

Number of seconds in 365 days

$= 365 \times 86400$ s[1 day = 86400 s]

$= 31536000$ s $= 3.15 \times 10^7$ s.

How will you estimate the diameter of the thread if you are given a thread and a metre scale ?

Wind a large number of turns n of the thread closely touching one another on a scale. Read the length l of the scale containing these turns. Then the diameter of the thread be l / n.

ASSIGNMENTS

Solve (Selina) exercise question answer and numerical related to the chapter 1.