1 Units and Measurements

PHYSICAL QUANTITIES

All quantities that can be measured are called physical quantities. eg. time, length, mass, force, work done, etc. In physics we study about physical quantities and their inter relationships.

MEASUREMENT

Measurement is the comparison of a quantity with a standard of the same physical quantity.

Different countries followed different standards.

UNITS

All physical quantities are measured w.r.t. standard magnitude of the **same** physical quantity and these standards are called UNITS. eg. second, meter, kilogram, etc.

So the four basic properties of units are:

1. They must be well defined.
2. They should be easily available and reproducible.
3. They should be invariable e.g. step as a unit of length is not invariable.
4. They should be accepted to all.

SET OF FUNDAMENTAL QUANTITIES

A set of physical quantities which are completely independent of each other and all other physical quantities can be expressed in terms of these physical quantities is called Set of Fundamental Quantities.

DERIVED PHYSICAL QUANTITIES

The physical quantities that can be expressed in terms of fundamental physical quantities are called derived physical quantities.eg. speed = distance/time.

SYSTEM OF UNITS

1. **FPS or British Engineering system :** In this system length, mass and time are taken as fundamential quantities and their base units are foot (ft), pound (lb) and second (s) respectively.
2. **CGS or Gaussian system :** In this system the fundamental quantities are length, mass and time and their respective units are centimetre (cm), gram (g) and second (s).
3. **MKS system :** In this system also the fundamental quantities are length, mass and time but their fundamental units are mete (m), kilogram (kg) and second (s) respectively.

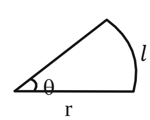
Units of some physical quantities in different systems

Type of physical Quantity	Physical Quantity	System		
		CGS	MKS	FPS
Fundamental	Length	cm	m	ft
	Mass	g	kg	lb
	Time	s	s	s

4. **International system (SI) of units :** This system is modification over the MKS system. Besides the three base units of MKS system four fundamental and two supplementary units are also included in this system.

Table : SI base quantities and their units

S. No.	Physical quantity	unit	Symbol
1	Length	metre	m
2	Mass	kilogram	kg
3	Time	second	s
4	Temperature	kelvin	kg
5	Electric current	ampere	A
6	Luminous Intensity	candela	cd
7	Amount of substance	mole	mol

Physical Quantity (SI Unit)	**Definition**
Length (m)	The distance travelled by light in vacuum in $\frac{1}{299,792,458}$ second is called **1 metre.**
Mass (kg)	The mass of a cylinder made of platinum-iridium alloy kept at International Bureau of Weights and Measures is defined as **1 kilogram**.
Time (s)	The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium-133 atom.
Electric Current (A)	If equal currents are maintained in the two parallel infinitely long wires of negligible cross-section, so that the force between them is 2×10^{-7} newton per metre of the wires, the current in any of the wires is called **1 Ampere**.
Thermodynamic Temperature (K)	The fraction $\frac{1}{273.16}$ of the thermodynamic temperature of triple point of water is called **1 Kelvin**
Luminous Intensity (cd)	**1 candela** is the luminous intensity of a blackbody of surface area $\frac{1}{600,000}\,m^2$ placed at the temperature of freezing platinum and at a pressure of 101,325 N/m^2, in the direction perpendicular to its surface.
Amount of substance (mole)	**The mole** is the amount of a substance that contains as many elementary entities as there are number of atoms in 0.012 kg of carbon-12.
There are two supplementary units too: **1. Plane angle (radian)** **2. Solid Angle (steradian)**	 angle = arc / radius $\theta = l/r$ Solid angle = Area/(radius^2)

DIMENSIONS AND DIMENSIONAL FORMULA

All the physical quantities of interest can be derived from the base quantities. "The power (exponent) of base quantity that enters into the expression of a physical quantity, is called the dimension of the quantity in that base. To make it clear, consider the physical quantity force.

$$\text{Force} = \text{mass} \times \text{acceleration}$$
$$= \text{mass} \times \frac{\text{length / time}}{\text{time}}$$
$$= \text{mass} \times \text{length} \times (\text{time})^{-2}$$

So the dimensions of force are 1 in mass, 1 in length and –2 in time. Thus

$$[\text{Force}] = MLT^{-2}$$

Similarly energy has dimensional formula given by

$$[\text{Energy}] = ML^2T^{-2}$$

i.e. energy has dimensions, 1 in mass, 2 in length and -2 in time.

Such an expression for a physical quantity in terms of base quantities is called dimensional formula.

Physical quantity can be further of four types :

(1) dimension less constant i.e. 1,2,3,π etc.
(2) Dimension less variable i.e. angle θ etc.
(3) dimensional constant i.e. G, h etc.
(4) Dimensional variable i.e. F, v, etc.

DIMENSIONAL EQUATION

Whenever the dimension of a physical quantity is equated with its dimensional formula, we get a dimensional equation.

PRINCIPLE OF HOMOGENEITY

The magnitude of a physical quantity may be added or subtracted from each other only if they have the same dimension, also the dimension on both sides of an equation must be same. This is called as principle of homogenity.

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Example 1: The distance covered by a particle in time t is going by $x = a + bt + ct^2 + dt^3$; find the dimensions of a, b, c and d.

Sol. The equation contains five terms. All of them should have the same dimensions. Since [x] = length, each of the remaining four must have the dimension of length.

Thus, $[a] = \text{length} = L$

$[bt] = L$, or $[b] = LT^{-1}$

$[ct^2] = L$, or $[c] = LT^{-2}$

and $[dt^3] = L$ or $[d] = LT^{-3}$

Example 2: Calculate the dimensional formula of energy from the equation $E = \frac{1}{2}mv^2$.

Sol. Dimensionally, E = mass × (velocity)^2, since $\frac{1}{2}$ is a number and has no dimension.

$$\text{or, } [E] = M \times \left(\frac{L}{T}\right)^2 = ML^2T^{-2}.$$

Example 3: Kinetic energy of a particle moving along elliptical trajectory is given by $K = \alpha s^2$ where s is the distance travelled by the particle. Determine dimensions of α.

Sol. $K = \alpha s^2$

$$[\alpha] = \frac{(ML^2T^{-2})}{(L^2)}$$

$$[\alpha] = M^1 L^0 T^{-2}$$

$$[\alpha] = M T^{-2}$$

Example 4: The position of a particle at time t, is given by the equation, $x(t) = \frac{v_0}{\alpha}(1 - e^{-\alpha t})$, where v_0 is a constant and $\alpha > 0$.

The dimensions of v_0 & α are respectively.

(a) $M^0 L^1 T^0$ & T^{-1}
(b) $M^0 L^1 T^{-1}$ & T
(*c*) $M^0 L^1 T^{-1}$ & T^{-1}
(*d*) $M^1 L^1 T^{-1}$ & LT^{-2}

Ans. **(c)**

Sol. $[v_0] = [x][\alpha] = M^0L^1T^{-1}$ & $[\alpha][t] = M^0L^0T^0$, $[\alpha] = M^0L^0T^{-1}$

USES OF DIMENSIONAL ANALYSIS

(I) To check the dimensional correctness of a given physical relation :

It is based on principle of homogeneity, which states that a given physical relation is dimensionally correct if the dimensions of the various terms on either side of the relation are the same.

Remark :

- Powers are dimensionless
- $\sin\theta$, e^θ, $\cos\theta$, $\log\theta$ gives dimensionless value and in above expression θ is dimensionless
- we can add or subtract quantity having same dimensions.

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Example 5: Check the accuracy of the relation

$$T = 2\pi\sqrt{\frac{L}{g}}$$

for a simple pendulum using dimensional analysis.

Sol. The dimenstions of LHS = the dimension of

$T = [M^0L^0T^1]$

The dimensions of $RHS = \left(\frac{\text{dim.of length}}{\text{dim.of acc}^n}\right)^{1/2}$

($\because$ 2π is a dimensionless const.)

$$= \left(\frac{L}{LT^{-2}}\right) = (T^2)^{1/2} = (T) = [M^0L^0T^1]$$

(II) To establish a relation between different physical quantities:

If we know the various factors on which a physical quantity depends, then we can find a relation among different factors by using principle of homogeneity.

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Example 6: Let us find an expression for the time period t of a simple pendulum. The time period t may possible depend upon (i) mass m of the bob of the pendulum, (ii) length l of pendulum, (iii) acceleration due to gravity g at the place where the pendulum is suspended.

Let (i) $t \propto m^a$ (ii) $t \propto l^b$ (iii) $t \propto g^c$

Combining all the three factors, we get

$t \propto m^a l^b g^c$ or $t = Km^a l^b g^c \theta^d$

where K is a dimensionless constant of proportionality.

Writing down the dimensions on either side of equation (i), we get

$[T] = [M^a][L^b][LT^{-2}]^c = [M^aL^{b+c}T^{-2c}]$

Comparing dimensions, a = 0, b + c = 0 , – 2c = 1

$\therefore$ a = 0, c = – 1/2, b = 1/2

From equation (i) $t = Km^0 l^{1/2} g^{-1/2}$

or $t = K\left(\frac{l}{g}\right)^{1/2} = K\sqrt{\frac{l}{g}}$

The value of K, as found by experiment or mathematical investigation, comes out to be 2π.

$$\therefore \quad t = 2\pi\sqrt{\frac{l}{g}}$$

Example 7: When a solid sphere moves through a liquid, the liquid opposes the motion with a force F. The magnitude of F depends on the coefficient of viscosity η of the liquid, the radius r of the sphere and the speed v of the sphere. Assuming that F is proportional to different powers of these quantities, guess a formula for F using the method of dimensions.

Sol. Suppose the formula is $F = k\,\eta^a r^b v^c$

Then, $MLT^{-2} = [ML^{-1}T^{-1}]^a L^b \left(\frac{L}{T}\right)^c$

$= M^a L^{-a+b+c} T^{-a-c}$

Equating the exponents of M, L and T from both sides,

a = 1

–a + b + c = 1

–a – c = –2

Solving these, a = 1, b = 1 and c = 1

Thus, the formula for F is $F = k\eta rv$.

Example 8: If P is the pressure of a gas and ρ is its density, then find the dimension of velocity

(*a*) $P^{1/2}\rho^{-1/2}$ (*b*) $P^{1/2}\rho^{1/2}$

(*c*) $P^{-1/2}\rho^{1/2}$ (*d*) $P^{-1/2}\rho^{-1/2}$

Sol. Method - I

$[P] = [ML^{-1}T^{-2}]$ ...(1)

$[\rho] = [ML^{-3}]$ ...(2)

Dividing eq. (1) by (2)

$[P\rho^{-1}] = [L^2T^{-2}]$

$\Rightarrow$ $[LT^{-1}] = [P^{1/2}\rho^{-1/2}]$

$\Rightarrow$ $[V] = [P^{1/2}\rho^{-1/2}]$

Method - II

$v \propto P^a \rho^b$

$v = kP^a \rho^b$

$[LT^{-1}] = [ML^{-1}T^{-2}]^a [ML^{-3}]^b$

$a = \frac{1}{2},\ b = -\frac{1}{2}$

$\Rightarrow$ $[V] = [P^{1/2}\rho^{-1/2}]$

Example 9: Find relationship between speed of sound in a medium (v), the elastic constant (E) and the density of the medium (ρ).

Sol. Let the speed depends upon elastic constant & density according to the relation

$v \propto E^a \rho^b$ or $v = KA^a\rho^b$ ...(1)

Where K is a dimensionless constant of proportionality

Considering dimensions of the quantities

$[v] = M^0 L T^{-1}$

$$[E] = \frac{[\text{stress}]}{[\text{strain}]} = \frac{[\text{force}]/[\text{area}]}{[\Delta l]/[l]} = \frac{[M^1L^1T^{-2}]/[L^2]}{[L^1]/[L^1]} = [M^1L^{-1}T^{-2}]$$

$\therefore$ $[E^a] = [M^a L^{-a} T^{-2a}]$

$[\rho] = [\text{mass}]/[\text{volume}] = [M]/[L^3] = [M^1L^{-3}T^0]$

$\therefore$ $[\rho^b] = [M^b L^{-3b} T^0]$

Equating the dimensions of the LHS and RHS quantities of equation (1), we get

$[M^0 L^1 T^{-1}] = [M^a L^{-a} T^{-2a}] = [M^b L^{-3b} T^0]$ or $[M^0 L^1 T^{-1}] = [M^{a+b} L^{-a-3b} T^{-2a}]$

Comparing the individual dimensions of M, L & T

$a + b = 0$ ...(2)

$-a - 3b = 1$ ...(3)

$-2a = -1$ ...(4)

Solving we get $a = \frac{1}{2}, b = -\frac{1}{2}$

Therefore the required relation is $v = K\sqrt{\frac{E}{\rho}}$

(III) To convert units of a physical quantity from one system of units to another :

It is based on the fact that,

Numerical value × unit = constant

So on changing unit, numerical value will also gets changed. If n_1 and n_2 are the numerical values of a given physical quantity and u_1 and u_2 be the units respectively in two different systems of units, then

$n_1u_1 = n_2u_2$

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$$

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Example 10: Convert 1 newton (SI unit of force) into dyne (CGS unit of force)

Sol. The dimensional equation of force is

$[F] = [M^1 L^1T^{-2}]$

Therefore if n_1, u_1 and n_2, u_2 corresponds to SI & CGS unit respectively, then

$$n_2 = n_1\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^1\left[\frac{T_1}{T_2}\right]^{-2}$$

$$= 1\left[\frac{\text{kg}}{\text{g}}\right]\left[\frac{\text{m}}{\text{cm}}\right]\left[\frac{\text{s}}{\text{s}}\right]^{-2} = 1\times1000\times100\times1 = 10^5$$

Example 11: A calorie is a unit of heat or energy and it equals about 4.2 J, where 1 J = 1 kg m²/s². Suppose we employ a system of units in which the unit of mass equals α kg, the unit of length equals β metre, the unit of time is γ second. Show that a calorie has a magnitude 4.2 $\alpha^{-1}\beta^{-2}\gamma^2$ in terms of the new units.

Sol. 1 cal = 4.2 kg m²s⁻²

SI	**New system**
$n_1 = 4.2$	$n_2 = ?$
$M_1 = 1$ kg	$M_2 = \alpha$ kg
$L_1 = 1$ m	$L_2 = \beta$ metre
$T_1 = 1$ s	$T_2 = \gamma$ second

Dimensional formula of energy is $[ML^2T^{-2}]$

Comparing with $[M^aL^bT^c]$,

We find that a = 1, b = 2, c = –2

Now, $n_2 = n_1\left[\frac{M_1}{M_2}\right]^a\left[\frac{L_1}{L_2}\right]^b\left[\frac{T_1}{T_2}\right]^c$

$$= 4.2\left[\frac{1\text{ kg}}{\alpha\text{ kg}}\right]^1\left[\frac{1\text{ m}}{\beta\text{ m}}\right]^2\left[\frac{1\text{ s}}{\gamma\text{ s}}\right]^{-2} = 4.2\ \alpha^{-1}\beta^{-2}\gamma^2$$

Example 12: Young's modulus of steel is 19×10^{10} N/m². Express it in dyne/cm². Here dyne is the CGS unit of force.

Sol. The unit of Young's modulus is N/m².

This suggest that it has dimensions of $\frac{\text{Force}}{(\text{Distance})^2}$.

Thus, $[Y] = \frac{[F]}{L^2} = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$.

N/m² is in SI units,

So, $1\ N/m^2 = (1\ kg)(1m)^{-1}(1s)^{-2}$

and $1\ dyne/cm^2 = (1g)(1cm)^{-1}(1s)^{-2}$

so, $\dfrac{1\ N/m^2}{1 dyne/cm^2}$

$$= \left(\frac{1kg}{1g}\right)\left(\frac{1m}{1cm}\right)^{-1}\left(\frac{1s}{1s}\right)^{-2} = 1000 \times \frac{1}{100} \times 1 = 10$$

or, $1\ N/m^2 = 10\ dyne/cm^2$

or, $19 \times 10^{10}\ N/m^2 = 19 \times 10^{11}\ dyne/m^2$.

Example 13: The dimensional formula for viscosity of fluids is,

$\eta = M^1L^{-1}T^{-1}$

Find how many poise (CGS unit of viscosity) is equal to 1 poiseuille (SI unit of viscosity).

Sol. $\eta = M^1\ L^{-1}\ T^{-1}$

1 CGS units = $g\ cm^{-1}\ s^{-1}$

1 SI units = $kg\ m^{-1}\ s^{-1}$

$= 1000\ g\ (100\ cm)^{-1}\ s^{-1}$

$= 10\ g\ cm^{-1}\ s^{-1}$

Thus, 1 Poiseuilli = 10 poise

Units and dimensions of some physical quantities

Quantity	SI Unit	Dimension
Density	kg/m^3	M/L^3
Force	newton (N)	ML/T^2
Work	joule (J)(=N-m)	ML^2/T^2
Energy	joule(J)	ML^2/T^2
Power	Watt (W) (=J/s)	ML^2/T^3
Momentum	kg-m/s	ML/T
Gravitational constant	$N\text{-}m^2/kg^2$	L^3/MT^2
Angular velocity	radian/s	T^{-1}
Angular acceleration	radian/s^2	T^{-2}
Angular momentum	$kg\text{-}m^2/s$	ML^2/T
Moment of inertia	$kg\text{-}m^2$	ML^2
Torque	N-m	ML^2/T^2
Angular frequency	radian/s	T^{-1}
Frequency	hertz (Hz)	T^{-1}
Period	s	T
Surface Tension	N/m	M/T^2
Coefficient of viscosity	$N\text{-}s/m^2$	M/LT
Wavelength	m	L
Intensity of wave	W/m^2	M/T^3
Temperature	Kelvin (K)	K
Specific heat capacity	J/kg-K	L^2/T^2K
Stefan's constant	$W/m^2\text{–}K^4$	M/T^3K^4
Heat	J	ML^2/T^2
Thermal conductivity	W/m-K	ML/T^3K

Current density	A/m^2	I/L^2
Electrical conductivity	$1/\Omega$-m(= mho/m)	I^2T^3/ML^3
Electric dipole moment	C-m	LIT
Electric field	V/m (=N/C)	ML/IT^3
Potential (voltage)	Volt (V) (=J/C)	ML^2/IT^3
Electric flux	V-m	ML^3/IT^3
Capacitance	Farad (F)	I^2T^4/ML^2
Electromotive force	Volt (V)	ML^2/IT^3
Resistance	ohm (Ω)	ML^2/I^2T^3
Permittivity of space	$C^2/N\text{-}m^2$ (=F/m)	I^2T^4/ML^3
Permeability of space	N/A^2	ML/I^2T^2
Magnetic field	Tesla (T) (= Wb/m^2)	M/IT^2
Magnetic flux	Weber (Wb)	ML^2/IT^2
Magnetic dipole moment	N-m/T	IL^2
Inductance	Henry (H)	ML^2/I^2T^2

LIMITATIONS OF DIMENSIONAL ANALYSIS

(i) It supplies no information about dimensionless constants and the nature (vector and scalar) of physical quantities.

(ii) This method fails to derive the exact form of a physical relation, if a physical quantity depends upon more than three other mechanical physical quantities.

(iii) This method is applicable only if relation is of product type. It fails in the case of exponential and trigonometric relations.

(iv) It doesnot predict numerical correctness of formula.

SI Prefixes : The magnitudes of physical quantites vary over a wide range. The mass of an electron is 9.1×10^{-31} kg and that of our earth is about 6×10^{24} kg. Standard prefixes for certain power of 10. Table shows these prefixes

Power of 10	Prefix	Symbol
12	tera	T
9	giga	G
6	mega	M
3	kilo	k
2	hecto	h
1	deka	da
–1	deci	d
–2	centi	c
–3	milli	m
–6	micro	μ
–9	nano	n
–12	pico	p
–15	femto	f

MEASUREMENT OF LENGTH

You are already familiar with some direct methods for the measurement of length. For example, a metre scale is used for lengths from 10^{-3} m to 10^2 m. A vernier callipers is used for lengths to an accuracy of 10^{-4} m. A screw gauge and a spherometer can be used to measure lengths as less as to 10^{-5} m. To measure lengths beyond these ranges, we make use of some special indirect methods.

Range of Lengths

The sizes of the objects we come across in the universe vary over a very wide range. These may vary from the size of the order of 10^{-4} m of the tiny nucleus of an atom to the size of the order of 10^{26} m of the extent of the observable universe.

We also use certain special length units for short and large lengths. These are

1 fermi = 1 f = 10^{-15} m

1 angstrom = 1 Å = 10^{-10} m (It is used mainly in measuring wavelength of light)

1 astronomical unit = 1 AU (average distance of the Sun from the Earth) = 1.496×10^{11} m

1 light year = 1 ly= 9.46×10^{15} m (distance that light travels with velocity of 3×10^8 m s^{-1} in 1 year)

1 parsec = 3.08×10^{16} m (Parsec is the distance at which average radius of earth's orbit subtends an angle of 1 arc second)

MEASUREMENT OF LARGE DISTANCES

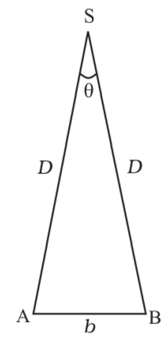
Parallax method:

Large distances such as the distance of a planet or a star from the earth cannot be measured directly with a metre scale. An important method in such cases is the parallax method. When you hold a pencil in front of you against some specific point on the background (a wall) and look at the pencil first through your left eye A (closing the right eye) and then look at the pencil through your right eye B (closing the left eye), you would notice that the position of the pencil seems to change with respect to the point on the wall. This is called **parallax**.

The distance between the two points of observation is called the basis. In this example, the basis is the distance between the eyes. To measure the distance D of a far away planet S by the parallax method, we observe it from two different positions (observatories) A and B on the Earth, separated by distance AB = b at the same time as shown in Figure.We measure the angle between the two directions along which the planet is viewed at these two points. The ΔASB in Figure represented by symbol θ is called the parallax angle or parallactic angle.

As the planet is very far away, $\frac{b}{D} << 1$ and therefore, θ is very small. Then we approximately take AB as an arc of length b of a circle with centre at S and the distance D as the radius AS = BS so that AB = b = D θ where θ is in radians.

$$D = \frac{b}{\theta} \qquad \text{....(i)}$$



Parallax method

Having determined D, we can employ a similar method to determine the size or angular diameter of the planet. If d is the diameter of the planet and α the angular size of the planet (the angle subtended by d at the earth), we have

$$\alpha = d/D \qquad \text{....(ii)}$$

The angle α can be measured from the same location on the earth. It is the angle between the two directions when two diametrically opposite points of the planet are viewed through the telescope. Since D is known, the diameter d of the planet can be determined using equation (ii).

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Example 14: The Sun's angular diameter is measured to be 1920''. The distance D of the Sun from the Earth is 1.496×10^{11} m. What is the diameter of the Sun ?

Sol. Sun's angular diameter a

$= 1920''$

$= 1920 \times 4.85 \times 10^{-6}$ rad

$= 9.31 \times 10^{-3}$ rad

Sun's diameter $d = \alpha D$

$= (9.31 \times 10^{-3}) \times (1.496 \times 10^{11})$ m

$= 1.39 \times 10^9$ m

ESTIMATION OF VERY SMALL DISTANCES

Size of a Molecule

To measure a very small size, like that of a molecule (10^{-8} m to 10^{-10} m), we have to adopt special methods. We cannot use a screw gauge or similar instruments. Even a microscope has certain limitations. An optical microscope uses visible light to 'look' at the system under investigation. As light has wave like features, the resolution to which an optical microscope can be used is the wavelength of light.

For visible light the range of wavelengths is from about 4000 Å to 7000 Å (1 angstrom = 1 Å = 10^{-10} m). Hence an optical microscope cannot resolve particles with sizes smaller than this. Instead of visible light, we can use an electron beam. Electron beams can be focussed by properly designed electric and magnetic fields. The resolution of such an electron microscope is limited finally by the fact that electrons can also behave as waves.

The wavelength of an electron can be as small as a fraction of an angstrom. Such electron microscopes with a resolution of 0.6 Å have been built. They can almost resolve atoms and molecules in a material. In recent times, tunnelling microscopy has been developed in which again the limit of resolution is better than an angstrom. It is possible to estimate the sizes of molecules.

A simple method for estimating the molecular size of oleic acid is given below. Oleic acid is a soapy liquid with large molecular size of the order of 10^{-9} m. The idea is to first form mono-molecular layer of oleic acid on water surface. We dissolve 1 cm^3 of oleic acid in alcohol to make a solution of 20 cm^3. Then we take 1 cm^3 of this solution and dilute it to 20 cm^3, using alcohol. So, the concentration of the solution is equal to

$\left(\frac{1}{20\times 20}\right)cm^3$ of oleic acid/cm^3 of solution. Next we lightly sprinkle some lycopodium powder on the surface of water in a large trough and we put one drop of this solution in the water.

The oleic acid drop spreads into a thin, large and roughly circular film of molecular thickness on water surface. Then, we quickly measure the diameter of the thin film to get its area A. Suppose we have dropped n drops in the water. Initially, we determine the approximate volume of each drop (V cm^3).

Volume of n drops of solution

$$= nV\ cm^3$$

Amount of oleic acid in this solution

$$= nV\left(\frac{1}{20\times 20}\right)cm^3$$

This solution of oleic acid spreads very fast on the surface of water and forms a very thin layer of thickness t. If this spreads to form a film of area A cm^2, then the thickness of the film

$$t = \frac{\text{volume of the film}}{\text{Area of the film}}$$

or, $$t = \frac{nV}{20\times 20A}\text{cm}$$

If we assume that the film has mono-molecular thickness, then this becomes the size or diameter of a molecule of oleic acid. The value of this thickness comes out to be of the order of 10^{-9} m.

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Example 15: If the size of a nucleus (inthe range of 10^{-15} to 10^{-11}m) is scaled up to the tip of a sharp pin, what roughly is the size of an atom ? Assume tip of the pin to be in the range 10^{-5} m to 10^{-4} m.)

Sol. The size of a nucleus is in the range of 10^{-15} m and 10^{-14} m. The tip of a sharp pin is taken to be in the range of 10^{-5} m and 10^{-4} m. Thus we are scaling up by a factor of 1m. An atom roughly of size 10^{-10} m will be scaled up to a size of 1 m. Thus a nucleus in an atom is as small in size as the tip of a sharp pin placed at the centre of a sphere of radius about a metre long.

ORDER-OF MAGNITUDE CALCULATIONS

$P = A \times 10^x$

$1/2 \le A < 5$

x is called order of magnitude

ERROR ANALYSIS IN EXPERIMENTS

Significant Figures or Digits

The *significant figures* (SF) in a measurement are the figures or digits that are known with certainity plus one that is uncertain.

Significant figures in a measured value of a physical quantity tell the number of digits in which we have confidence. Larger the number of significant figures obtained in a measurement, greater is its accuracy and vice versa.

1. Rules to find out the number of significant figures :

I Rule : All the non-zero digits are significant e.g. 1984 has 4 SF.

II Rule : All the zeros between two non-zero digits are significant. e.g. 10806 has 5 SF.

III Rule : All the zeros to the left of first non-zero digit are not significant. e.g.00108 has 3 SF.

IV Rule : If the number is less than 1, zeros on the right of the decimal point but to the left of the first non-zero digit are not significant. e.g. 0.002308 has 4 SF.

V Rule : The trailing zeros (zeros to the right of the last non-zero digit) in a number with a decimal point are significant. e.g. 01.080 has 4 SF.

VI Rule : The trailing zeros in a number without a decimal point are not significant e.g. 010100 has 3 SF. But if the number comes from some actual measurement then the trailing zeros become significant. e.g. m = 100 kg has 3 SF.

VII Rule : When the number is expressed in exponential form, the exponential term does not affect the number of S.F. For example in $x = 12.3 = 1.23 \times 10^1 = .123 \times 10^2 = 0.0123 \times 10^3 = 123 \times 10^{-1}$ each term has 3 SF only.

2. Rules for arithmetical operations with significant figures :

I Rule : In addition or subtraction the number of decimal places in the result should be equal to the number of decimal places of that term in the operation which contain lesser number of decimal places. e.g. $12.587 - 12.5 = 0.087 = 0.1$ ($\because$ second term contain lesser i.e. one decimal place)

II Rule : In multiplication or division, the number of SF in the product or quotient is same as the smallest number of SF in any of the factors. e.g. $5.0 \times 0.125 = 0.625 = 0.62$

To avoid the confusion regarding the trailing zeros of the numbers without the decimal point the best way is to report every measurement in *scientific notation* (in the power of 10). In this notation every number is expressed in the form $a \times 10^b$, where a is the base number between 1 and 10 and b is any positive or negative exponent of 10. The base number (a) is written in decimal form with the decimal after the first digit. While counting the number of SF only base number is considered (Rule VII).

The *change in the unit of measurement of a quantity does not affect the number of SF*. For example in 2.308 cm = 23.08 mm = 0.02308 m = 23080 μm each term has 4 SF.

TRAIN YOUR BRAIN

Example 16: Write down the number of significant figures in the following.

(a)	165 3SF	(following rule I)
(b)	2.05 3 SF	(following rules I & II)
(c)	34.000 m 5 SF	(following rules I & V)
(d)	0.005 1 SF	(following rules I & IV)
(e)	0.02340 N m^{-1} 4 SF	(following rules I, IV & V)
(f)	26900 3 SF	(see rule VI)
(g)	26900 kg 5 SF	(see rule VI)

Example 17: The length, breadth and thickness of a metal sheet are 4.234 m, 1.005 m and 2.01 cm respectively. Give the area and volume of the sheet to correct number of significant figures.

Sol. length (l) = 4.234 m breadth (b) = 1.005 m

thickness (t) = 2.01 cm = 2.01×10^{-2} m

Therefore area of the sheet

$= 2\,(l \times b + b \times t + t \times l)$

$= 2\,(4.234 \times 1.005 + 1.005 \times 0.0201 + 0.0201 \times 4.234)\ m^2$

$= 2\,(4.3604739)\ m^2 = 8.720978\ m^2$

Since area can contain a maximum of 3 SF (Rule II of article 4.2) therefore, rounding off, we get

Area = $8.72\ m^2$

Like wise volume = $l \times b \times t = 4.234 \times 1.005 \times 0.0201\ m^3 = 0.0855289\ m^3$

Since volume can contain 3 SF, therefore, rounding off, we get

Volume = $0.0855\ m^3$

ROUNDING OFF

To represent the result of any computation containing more than one uncertain digit, it is *rounded off* to appropriate number of significant figures.

Rules for rounding off the numbers :

I Rule : If the digit to be rounded off is more than 5, then the preceding digit is increased by one. e.g. $6.87 \approx 6.9$

II Rule : If the digit to be rounded off is less than 5, than the preceding digit is unaffected and is left unchanged. e.g. $3.94 \approx 3.9$

III Rule : If the digit to be rounded off is 5 then the preceding digit is increased by one if it is odd and is left unchanged if it is even. e.g. $14.35 \approx 14.4$ and $14.45 \approx 14.4$

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Example 18: The following values can be rounded off to four significant figures as follows :

(a) $36.879 \approx 36.88$ ($\because 9 > 5 \therefore 7$ is increased by one i.e.I Rule)

(b) $1.0084 \approx 1.008$ ($\because 4 < 5 \therefore 8$ is left unchanged i.e. II Rule)

(c) $11.115 \approx 11.12$ ($\because$ last 1 is odd it is increased by one i.e.III Rule)

(d) $11.1250 \approx 11.12$ ($\because 2$ is even it is left unchanged i.e. III Rule)

(e) $11.1251 \approx 11.13$ ($\because 51 > 50 \therefore$ 2 is incresed by one i.e. I Rule)

ERRORS IN MEASUREMENT

Definition

The difference between the true value and the measured value of a quantity is known as the error of measurement.

Classification of errors

Errors may arise from different sources and are usually classified as follows :-

Systematic or Controllable Errors : Systematic errors are the errors whose causes are known. They can be either positive or negative. Due to the known causes these errors can be minimised. Systematic errors can further be classified into three categories:

(i) Instrumental errors :- These errors are due to imperfect design or erroneous manufacture or misuse of the measuring instrument. These can be reduced by using more accurate instruments.

(ii) Environmental errors :- These errors are due to the changes in external environmental conditions such as temperature, pressure, humidity, dust, vibrations or magnetic and electrostatic fields.

(iii) Observational errors :- These errors arise due to improper setting of the apparatus or carelessness in taking observations.

Random Errors: These errors are due to unknown causes. Therefore they occur irregularly and are variable in magnitude and sign. Since the causes of these errors are not known precisely they can not be eliminated completely. For example, when the same person repeats the same observation in the same conditions, he may get different readings different times.

Random erros can be reduced by repeating the observation a large number of times and taking the arithmetic mean of all the obervations. This mean value would be very close to the most accurate reading.

Note :- If the number of observations is made n times then the random error reduces to $\left(\frac{1}{n}\right)$ times.

Example :- If the random error in the arithmetic mean of 100 observations is 'x' then the random error in the arithmetic mean of 500 observations will be $\frac{x}{5}$

Gross Errors : Gross errors arise due to human carelessness and mistakes in reading the instruments or calculating and recording the measurement results.

For example :-

(i) Reading instrument without proper initial settings.

(ii) Taking the observations wrongly without taking necessary precautions.

(iii) Exhibiting mistakes in recording the observations.

(iv) Putting improper values of the observations in calculations.

These errors can be minimised by increasing the sincerity and alertness of the observer.

REPRESENTATION OF ERRORS

Errors can be expressed in the following ways:-

1. **Mean Absolute Error :-** It is given by

$$a_m = \frac{a_1 + a_2 + \ldots\ldots + a_n}{n}$$

$$a_m = \frac{a_1 + a_2 + \ldots\ldots + a_n}{n}$$ = is taken as the true value of a quantity, if the same is not known.

$\Delta a_1 = a_m - a_1$
$\Delta a_2 = a_m - a_2$
....
$\Delta a_n = a_m - a_n$

Final result of measurement may be written as :

$a = a_m \pm \Delta\bar{a}$

2. **Relative Error or Fractional Error :** It is given by

$$\frac{\overline{\Delta a}}{a_m} = \frac{\text{Mean absolute Error}}{\text{Mean value of measurement}}$$

3. **Percentage Error** $= \frac{\overline{\Delta a}}{a_m} \times 100\%$

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Example 19: The period of oscillation of a simple pendulum in an experiment is recorded as 2.63 s, 2.56 s, 2.42 s, 2.71 s and 2.80 s respectively. find (i) mean time period (ii) absolute error in each observation and percentage error.

Sol. (i) Mean time period is given by

$$T = \frac{2.63+2.56+2.42+2.71+2.80}{5}$$

$$= \frac{13.12}{5} = 2.62s$$

(ii) The absolute error in each observation is
$2.62-2.63=-0.01, 2.62-2.56=0.06, 2.62-2.42=0.20,$
$2.62-2.71=-0.09, 2.62-2.80=-0.18$

Mean absolute error, $\overline{\Delta T} = \frac{\Sigma|\Delta T|}{5}$

$$= \frac{0.01+0.06+0.2+0.09+0.18}{5} = 0.11\text{sec}$$

$\therefore$ Percentage error

$$= \frac{\overline{\Delta T}}{\overline{T}} \times 100 = \frac{0.11}{2.62} \times 100 = 4.2\%$$

COMBINATION OF ERRORS

(i) In Sum : If $Z = A + B$, then $\Delta Z = \Delta A + \Delta B$, maximum fractional error in this case $\frac{\Delta Z}{Z} = \frac{\Delta A}{A+B} + \frac{\Delta B}{A+B}$

i.e. when two physical quantities are added then the maximum absolute error in the result is the sum of the absolute errors of the individual quantities.

(ii) In Difference : If $Z = A - B$, then maximum absolute error is $\Delta Z = \Delta A + \Delta B$ and maximum fractional error in this case $\frac{\Delta Z}{Z} = \frac{\Delta A}{A-B} + \frac{\Delta B}{A-B}$

(iii) In Product : If $Z = AB$, then the maximum fractional error,

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

where $\Delta Z/Z$ is known as fractional error.

(iv) In Division : If $Z = A/B$, then maximum fractional error is

$$\frac{\Delta Z}{Z} = \frac{\Delta A}{A} + \frac{\Delta B}{B}$$

(v) In Power : If $Z = A^n$ then $\frac{\Delta Z}{Z} = n\frac{\Delta A}{A}$

In more general form if $Z = \frac{A^x B^y}{C^q}$

then the maximum fractional error in Z is

$$\frac{\Delta Z}{Z} = x\frac{\Delta A}{A} + y\frac{\Delta B}{B} + q\frac{\Delta C}{C}$$

Applications:

1. For a simple pendulum, $T \propto l^{1/2}$

$$\Rightarrow \frac{\Delta T}{T} = \frac{1}{2}\frac{\Delta l}{l}$$

2. For a sphere

$$A = 4\pi r^2, V = \frac{4}{3}\pi r^3$$

$$\Rightarrow \frac{\Delta A}{A} = 2.\frac{\Delta r}{r} \text{ and } \frac{\Delta V}{V} = 3.\frac{\Delta r}{r}$$

3. When two resistors R_1 and R_2 are connected

(a) In series

$$R_s = R_1 + R_2$$

$$\Rightarrow \Delta R_s = \Delta R_1 + \Delta R_2$$

$$\frac{\Delta R_s}{R_s} = \frac{\Delta R_1 + \Delta R_2}{R_1 + R_2}$$

(b) In parallel,

$$\frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2}$$

$$\Rightarrow \frac{\Delta R_p}{R_p^2} = \frac{\Delta R_1}{R_1^2} + \frac{\Delta R_2}{R_2^2}$$

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Example 20: In an experiment of simple pendulum, the errors in the measurement of length of the pendulum (L) and time period (T) are 3% and 2% respectively. The maximum percentage error in the value of $\frac{L}{T^2}$ is

(*a*) 5% (*b*) 7%
(*c*) 8% (*d*) 1%

Sol. (c) Maximum percentage in the value of $\frac{L}{T^2}$

$$= \frac{\Delta L}{L} \times 100\% + 2\frac{\Delta T}{T} \times 100\%$$

$$= 3 + 2 \times 2$$

$$= 7\%$$

Example 21: If $X = \dfrac{A^2\sqrt{B}}{C}$, then

(*a*) $\Delta X = \Delta A + \Delta B + \Delta C$

(*b*) $\dfrac{\Delta X}{X} = \dfrac{2\Delta A}{A} + \dfrac{\Delta B}{B} + \dfrac{\Delta C}{C}$

(*c*) $\dfrac{\Delta X}{X} = \dfrac{2\Delta A}{A} + \dfrac{\Delta B}{2B} + \dfrac{\Delta C}{C}$

(*d*) $\dfrac{\Delta X}{X} = \dfrac{\Delta A}{A} + \dfrac{\Delta B}{B} + \dfrac{\Delta C}{C}$

Ans. (c)

Sol. $\cdot\ X = A^2 B^{1/2} C \quad \therefore \quad \dfrac{\Delta X}{X} = \dfrac{2\Delta A}{A} + \dfrac{\Delta B}{2B} + \dfrac{\Delta C}{C}$

Example 22: A body travels uniformly a distance (13.8 ± 0.2) m in a time (4.0 ± 0.3) s. Calculate its velocity with error limits. What is the percentage error in velocity?

Sol. Given distance, $s = (13.8 \pm 0.2)$ m

and time $t = (4.0 \pm 0.3)$ s

Velocity $v = \dfrac{s}{t} = \dfrac{13.8}{4.0} = 3.45\text{ms}^{-1} = 3.5\text{ms}^{-1}$

$$\frac{\Delta v}{v} = \pm\left(\frac{\Delta s}{s} + \frac{\Delta t}{t}\right) = \pm\left(\frac{0.2}{13.8} + \frac{0.3}{4.0}\right)$$

$$= \pm\left(\frac{0.8 + 4.14}{13.8 \times 40.}\right) = \pm\left(\frac{0.2}{13.8} + \frac{0.3}{4.0}\right)$$

$\therefore \quad \Delta v = \pm 0.0895 \times V = \pm 0.0895 \times 3.45 = \pm 0.3087 = \pm 0.31$

Hence $v = (3.5 \pm 0.31)$ m s^{-1}

Percentage error in velocity

$= \dfrac{\Delta v}{v} \times 100 = \pm 0.0895 \times 100 = \pm 8.95\% = \pm 9\%$

Example 23: The heat generated in a circuit is given by $Q = I^2 Rt$, where I is current, R is resistance and t is time. If the percentage errors in measuring I, R and t are 2%, 1% and 1% respectively, then the maximum error in measuring heat will be–

(*a*) 2 % (*b*) 3 %

(*c*) 4 % (*d*) 6 %

Ans. (d)

Sol. $Q = I^2 Rt$ error, given I = 2%

R = 1%

t = 1.1%

Maximum possible % error

$= 2 \times 2\% + 1 \times 1\% + 1 \times 1\% = 6\%$

Example 24: Given : Resistance, $R_1 = (8 \pm 0.4)\ \Omega$ and Resistance, $R_2 = (8 \pm 0.6)\ \Omega$. What is the net resistance when R_1 and R_2 are connected in series?

(*a*) $(16 \pm 0.4)\ \Omega$

(*b*) $(16 \pm 0.6)\ \Omega$

(*c*) $(16 \pm 1.0)\ \Omega$

(*d*) $(16 \pm 0.2)\ \Omega$

Ans. **(c)**

Sol. $R_1 = (8 \pm 0.4)\Omega$

$R_2 = (8 \pm 0.6)\ \Omega$

$R_s = R_1 + R_2 = (16 \pm 1.0)\Omega$

Example 25: The following observations were taken for determining surface tension of water by capillary tube method: Diameter of capillary, $D = 1.25 \times 10^{-2}$ m and rise of water in capillary, $h = 1.45 \times 10^{-2}$ m.

Taking $g = 9.80$ ms^{-2} and using the relation

$T = (rgh/2) \times 10^3$ Nm^{-1}, what is the possible error in surface tension T ?

(*a*) 2.4 % (*b*) 15 %

(*c*) 1.6 % (d) 0.15 %

Ans. **(c)**

Sol. Given $T = (rgh/2) \times 10^3$ Nm^{-1},

$D = 1.25 \times 10^{-2}$ m, $h = 1.45 \times 10^{-2}$ m,

$g = 9.80$ ms^{-2}

$$\frac{\delta T}{T} = \frac{\delta r}{r} + \frac{\delta h}{h} + \frac{\delta g}{g}$$

after apply the above values in this relation we get $\delta T\% = 1.6\%$

MEASURING INSTRUMENT

Measurement is an important aspect of physics. Whenever we want to know about a physical quantity, we take its measurement first of all.

Instruments used in measurement are called **measuring instruments.**

Least Count: The least value of a quantity, which the instrument can measure accurately, is called the least count of the instrument.

Error: The measured value of the physical quantity is usually different from its true value. The result of every measurement by any measuring instrument is an approximate number, which contains some uncertainty. This uncertainty is called error. Every calculated quantity, which is based on measured values, has an error.

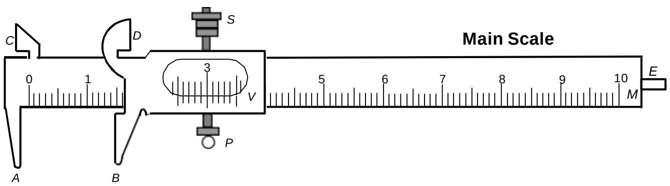
Accuracy and Precision: The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity. Precision tells us to what resolution or limit the quantity is measured.

VERNIER CALLIPERS

It is a device used to measure accurately upto 0.1 mm. There are two scales in the vernier callipers, vernier scale and main scale. The main scale is fixed whereas the vernier scale is movable along the main scale.

Its main parts are as follows:

Main scale: It consists of a steel metallic strip *M*, graduated in cm and *mm* at one edge and in inches and tenth of an inch at the other edge on same side. It carries fixed jaws *A* and *C* projected at right angle to the scale as shown in figure.



Vernier Scale: A vernier *V* slides on the strip *M*. It can be fixed in any position by screw *S*. It is graduated on both sides. The side of the vernier scale which slides over the *mm* side has ten divisions over a length of 9 mm, i.e., over 9 main scale divisions and the side of the vernier scale which slides over the inches side has 10 divisions over a length of 0.9 inch, i.e., over 9 main scale divisions.

Movable Jaws: The vernier scale carries jaws *B* and *D* projecting at right angle to the main scale. These are called movable jaws. When vernier scale is pushed towards *A* and *C*, then as *B* touches *A*, straight side of *D* will touch straight side of *C*. In this position, in case of an instrument free from errors, zeros of vernier scale will coincide with zeros of main scales, on both the cm and inch scales.

(The object whose length or external diameter is to be measured is held between the jaws *A* and *B*, while the straight edges of *C* and *D* are used for measuring the internal diameter of a hollow object).

Metallic Strip: There is a thin metallic strip *E* attached to the back side of *M* and connected with vernier scale. When the jaws *A* and *B* touch each other, the edge of strip *E* touches the edge of *M*. When the jaws *A* and *B* are separated, *E* moves outwards. The strip E is used for measuring the depth of a vessel.

Determination of least count (Vernier Constant)

Note the value of the main scale division and count the number *n* of vernier scale divisions. Slide the movable jaw till the zero of vernier scale coincides with any of the mark of the main scale and find the number of divisions (n – 1) on the main scale coinciding with *n* divisions of vernier scale. Then

$$nV.S.D. = (n-1)\,M.S.D. \text{ or } 1\,V.S.D. = \left(\frac{n-1}{n}\right) M.S.D.$$

$$\text{or} \quad V.C. = 1\,M.S.D. - 1\,V.S.D. = \left(1-\frac{n-1}{n}\right)\text{M.S.D.}$$

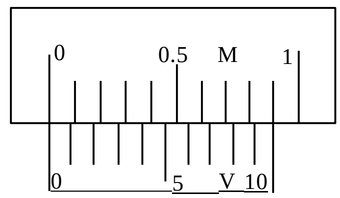
$$= \frac{1}{n}\text{ M.S.D.}$$

Determination of zero error and zero correction

For this purpose, movable jaw *B* is brought in contact with fixed jaw *A*.

One of the following situations will arise.

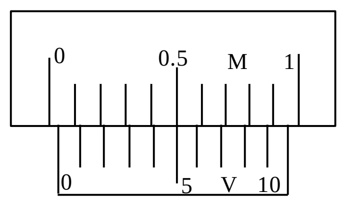
(i) Zero of Vernier scale coincides with zero of main scale (see figure)



In this case, zero error and zero correction, both are nil.

Actual length = observed (measured) length.

(ii) Zero of vernier scale lies on the right of zero of main scale (see figure)



Here 5th vernier scale division is coinciding with any main sale division.

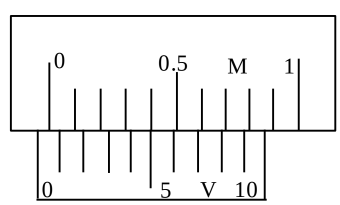
Hence, $N = 0$, $n = 5$, L.C. = 0.01 cm.

Zero error $N = n \times$ (L.C.) $= 0 + 5 \times 0.01 = +\,0.05$ cm

Zero correction = – 0.05 cm.

Actual length will be 0.05 cm less than the observed (measured) length.

(iii) zero of the vernier scale lies left of the main scale.



Here, 5th vernier scale division is coinciding with any main scale division.

In this case, zero of vernier scale lies on the right of –0.1 cm reading on main scale.

Hence, $N = -0.1$ cm, $n = 5$, L.C. = 0.01 cm

Zero error = $N + n \times$ (L.C.) = $-0.1 + 5 \times 0.01 = -0.05$ cm.

Zero correction = +0.05 cm.

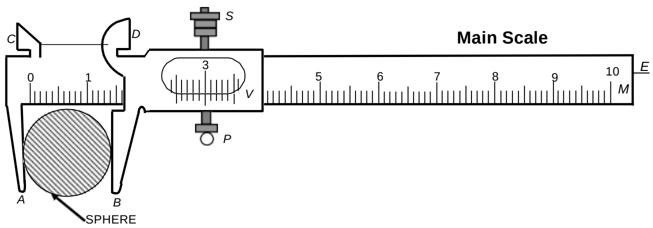
Actual length will be 0.05 cm more than the observed (measured) length.

Experiment

Aim: To measure the diameter of a small spherical/cylindrical body, using a vernier callipers.

Apparatus: Vernier callipers, a spherical (pendulum bob) or a cylinder.

Diagram:



Theory: If with the body between the jaws, the zero of vernier scale lies ahead of Nth division of main scale, then main scale reading (M.S.R.) = N.

If n^{th} division of vernier scale coincides with any division of main scale, then vernier scale reading (V.S.R.)

= $n \times$ (L.C.) (L.C. is least count of vernier callipers)

= $n \times$ (V.C.) (V.C. is vernier constant of vernier callipers)

Total reading, $T.R. = M.S.R. + V.S.R. = N + n \times (V.C.)$

Precautions (to be taken)

1. Motion of vernier scale on main scale should be made smooth (by oiling if necessary).
2. Vernier constant and zero error should be carefully found and properly recored.
3. The body should be gripped between the jaws firmly but gently (without undue pressure on it from the jaws).
4. Observations should be taken at right angles at one place and taken at least at three different places.

Sources of Error

1. The vernier scale may be loose on main scale.
2. The jaws may not be at right angles to the main scale.
3. The graduations on scale may not be correct and clear.
4. Parallax may be there in taking observations.

TRAIN YOUR BRAIN

Example 26: The least count of vernier callipers is 0.1 mm. The main scale reading before the zero of the vernier scale is 10 and the zeroth division of the vernier scale coincides with the main scale division. Given that each main scale division is 1 mm, what is the measured value?

Sol. Length measured with vernier callipers

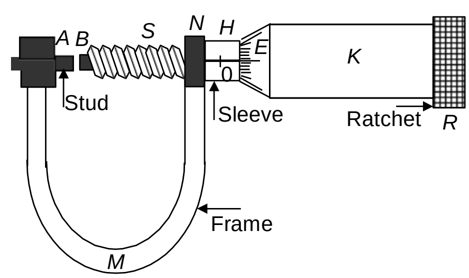
= reading before the zero of vernier scale + number of vernier divisions coinciding

with any main scale division × least count

$= 10\text{ mm} + 0 \times 0.1\text{ mm} = 10\text{ mm} = \mathbf{1.00\ cm}$

SCREW GAUGE

This instrument (shown in figure) works on the principle of micrometer screw. It consists of a U-shaped frame *M*. At one end of it is fixed a small metal piece *A* of gun metal. It is called stud and it has a plane face. The other end *N* of *M* carries a cylindrical hub *H*. The hub extends few millimetre beyond the end of the frame. On the tubular hub along its axis, a line is drawn known as reference line. On the reference line graduations are in millimetre and half millimeter depending upon the pitch of the screw. This scale is called linear scale or pitch scale. A nut is threaded through the hub and the frame *N*. Through the nut moves a screw *S* made of gun metal. The front face *B* of the screw, facing the plane face *A*, is also plane. A hollow cylindrical cap *K*, is capable of rotating over the hub when screw is rotated. It is attached to the right hand end of the screw. As the cap is rotated the screw either moves in or out. The bevelled surface *E* of the cap *K* is divided into 50 or 100 equal parts. It is called the circular scale or head scale. Right hand end *R* of *K* is milled for proper grip.



In most of the instrument the milled head *R* is not fixed to the screw head but turns it by a spring and ratchet arrangement such that when the body is just held between faces *A* and *B*, the spring yields and milled head *R* turns without moving in the screw.

In an accurately adjusted instrument when the faces *A* and *B* are just touching each other, the zero marks of circular scale and pitch scale exactly coincide.

Determination of least count of screw gauge

Note the value of linear (pitch) scale division. Rotate screw to bring zero mark on circular (head) scale on reference line. Note linear scale reading i.e. number of divisions of linear scale uncovered by the cap.

Now give the screw a few known number of rotations. (one rotation completed when zero of circular scale again arrives on the reference line). Again note the linear scale reading. Find difference of two readings on linear scale to find distance moved by the screw.

Then, pitch of the screw

$$= \frac{\text{Distance moved by in n rotation}}{\text{No. of full rotation (n)}}$$

Now count the total number of divisions on circular (head) scale.

Then, least count

$$= \frac{\text{Pitch}}{\text{Total number of divisions on the circular scale}}$$

The least count is generally 0.001 cm.

Determination of zero error and zero correction

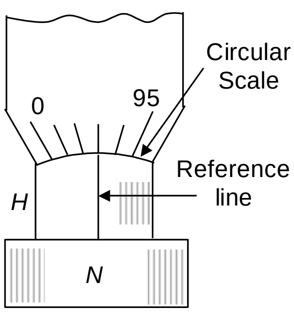
For this purpose, the screw is rotated forward till plane face *B* of the screw just touches the fixed plane face *A* of the stud and edge of cap comes on zero mark of linear scale. Screw gauge is held keeping the linear scale vertical with its zero downwards.

One of the following three situations will arise.

(i) **Zero mark of circular scale comes on the reference line** (see figure)

In this case, zero error and zero correction, both are nil

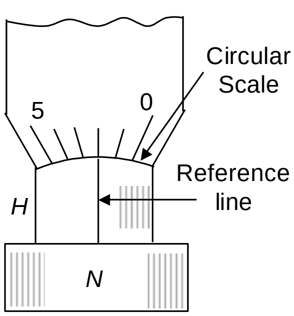
Actual thickness = Observed (measured) thickness.



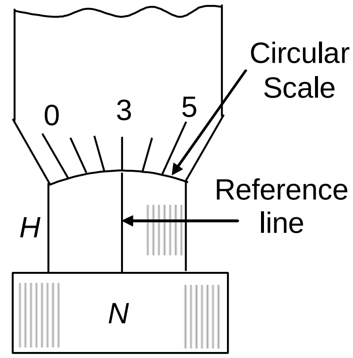
(ii) **Zero mark of circular scale remains on right of reference line and does not cross** it (see figure).

Here 2nd division on circular scale comes on reference line. Zero reading is already 0.02 mm. It makes zero error + 0.02 mm and zero correction – 0.02 mm.

Actual thickness will be 0.02 mm less than the observed (measured) thickness.



(iii) **Zero mark of circular scale goes to left on reference line after crossing it (see figure).** Here zero of circular scale has advanced from reference line by 3 divisions on circular scale. A backward rotation by 0.03 mm will make reading zero. It makes zero error – 0.03 mm & zero correction + 0.03 mm.



Actual thickness will be 0.03 mm more than the observed (measured) thickness.

Experiment

Aim: To measure diameter of a given wire using a screw gauge and find its volume.

Apparatus: Screw gauge, wire, half metre rod (scale).

Theory:

(1) Determine of least count of screw gauge

(2) If with the wire between plane faces *A* and *B*, the edge of the cap lies ahead of N^{th} division of linear scale.

Then, linear scale reading (L.S.R.) = N

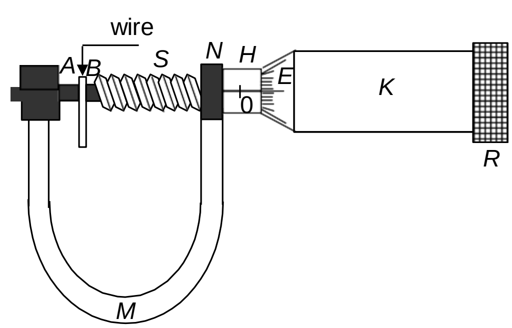
If nth division of circular scale lies over reference line.

Then, circular scale reading (C.S.R.) = $n \times$ (L.C.)

(L.C. is least count of screw gauge)

Total reading (T.R.) = L.S.R. + C.S.R. = $N + n \times$ (L.C.)

(3) If D be the mean diameter and l be the mean length of the wire. Then volume of the wire, $V = \pi \left(\frac{D}{2}\right)^2 l$



Calculation

Mean diameter of the wire,

$$D = \frac{D_1(a)+D_1(b)+.....+D_5(a)+D_5(b)}{10} = ...mm$$

$$= \dots cm$$

Mean length of the wire,

$$l = \frac{l_1 + l_2 + l_3}{3} = ...cm$$

Volume of the wire

$$V = \pi\left(\frac{D}{2}\right)^2 l = \dots cm^3$$

Result The volume of the given wire is = … cm^3

Precaution (to be taken)

1. While taking an observation, the screw must always be turned only in one direction so as to avoid the backlash error.
2. At each place, take readings in pairs i.e. in two directions at right angles to each other.
3. The wire must be straight and free from kinks.
4. Always rotate the screw by the ratchet and stop as soon as it gives one tick sound only.
5. While taking a reading, rotate the screw in only one direction so as to avoid the backlash error.

Sources of Error

(i) The screw may have friction.
(ii) The screw gauge may have back-lash error.
(iii) Circular scale divisions may not be of equal size.
(vi) The wire may not be uniform.

TRAIN YOUR BRAIN

Example 27: A vernier callipers has its main scale of 10 cm equally divided into 200 equal parts. Its vernier scale of 25 divisions coincides with 12 mm on the main scale. The least count of the instrument is–

(*a*) 0.020 cm
(*b*) 0.002 cm
(*c*) 0.010 cm
(*d*) 0.001 cm

Ans. **(b)**

Sol. In vernier calliper main scale 10 cm.

10 cm divided in 200 divisions. $1 \text{ div.} = \frac{10}{200}$

$= 0.05 \text{ cm.}$

$25V = 24S.$

$$V = \frac{24}{25}S$$

$$S - V = S - \frac{24}{25}S = \frac{1}{25}S$$

$\because 1S = 0.05$ cm

or vernier constant $= \frac{0.05}{25} = 0.002$ cm

Least count = 0.002 cm

Example 28: One centimetre on the main scale of vernier callipers is divided into ten equal parts. If 10 divisions of vernier scale coincide with 8 small divisions of the main scale, the least count of the callipers is –

(*a*) 0.005 cm (*b*) 0.05 cm
(*c*) 0.02 cm (*d*) 0.01 cm

Ans. **(c)**

Sol. 1 main scale div = 0.1 cm

$10V = 8S$

$$V = \frac{8}{10} s.$$

$$S - V = S - \frac{8}{10}S = \frac{2}{10}S. = \frac{1}{5} S$$

But $1S = 0.1$ cm

$$= \frac{0.1}{5} = 0.02 \text{ cm}$$

Least count = 0.02 cm

Example 29: In four complete revolutions of the cap, the distance traveled on the pitch scale is 2mm. If there are fifty divisions on the circular scale, then

(i) Calculate the pitch of the screw gauge
(ii) Calculate the least count of the screw gauge

Ans. Pitch = 0.5 mm, L.C. = 0.001 cm

Sol. Pitch of screw = Linear distance traveled in one Revolution

$$P = \frac{2mm}{4} = 0.5 \text{ mm} = 0.05 \text{ cm}$$

Least count

$$= \frac{\text{Pitch}}{\text{no. of divisions in circular scale}} = \frac{0.05}{50} = 0.001 \text{ cm}$$

Example 30: The pitch of a screw gauge 0.5 mm and there are 50 divisions on the circular scale. In measuring the thickness of a metal plate, there are five divisions on the pitch scale (or main scale) and thirty fourth division coincides with the reference line. Calculate the thickness of the metal plate.

Ans. Thickness of sheet = 2.84 mm.

Sol. Pitch of screw = 0.5 mm.

$$L.C. = \frac{0.5}{50} = 0.01 \text{ mm.}$$

$\text{Thickness} = (5 \times 0.5 + 34 \times 0.01)$ mm

$= (2.5 + 0.34) = 2.84$ mm

Topicwise Questions

UNIT AND DIMENSIONS

Units, System of Units

1. A unit less quantity
   (a) never has a nonzero dimension
   (b) always has a nonzero dimension
   (c) may have a nonzero dimension
   (d) does not exit

2. Which of the following is not the name of a physical quantity?
   (*a*) kilogram (*b*) impulse
   (*c*) energy (*d*) density

3. PARSEC is a unit of
   (a) Time (*b*) Angle
   (*c*) Distance (*d*) Velocity

4. Which of the following system of units is NOT based on the unit of mass, length and time alone
   (a) FPS (*b*) SI (*c*) CGS (*d*) MKS

5. In the S.I. system the unit of energy is-
   (*a*) erg (*b*) calorie
   (*c*) joule (*d*) electron volt

6. The SI unit of the universal gravitational constant G is
   (a) Nm kg^{-2} (*b*) Nm^2kg^{-2} (*c*) $Nm^2 kg^{-1}$ (*d*) $Nmkg^{-1}$

7. Surface tension has unit of-
   (a) $Joule.m^2$ (*b*) $Joule.m^{-2}$ (*c*) $Joule.m^{-1}$ (*d*) $Joule.m^3$

8. The specific resistance has the unit of-
   (a) ohm/m (*b*) ohm/m^2 (*c*) $ohm.m^2$ (*d*) ohm.m

9. The unit of magnetic moment is-
   (a) amp m^2 (*b*) amp m^{-2} (*c*) amp m (*d*) amp m^{-1}

10. The SI unit of the universal gas constant R is:
    (*a*) erg K^{-1} mol^{-1} (*b*) watt K^{-1} mol^{-1}
    (*c*) newton K^{-1} mol^{-1} (*d*) joule K^{-1} mol^{-1}

11. The SI unit of Stefan's constant is:
    (*a*) Ws^{-1} m^{-2} K^{-4} (*b*) J s m^{-1} K^{-1}
    (*c*) J s^{-1} m^{-2} K^{-1} (*d*) W m^{-2} K^{-4}

Dimension, Finding Dimensional Formula

12. In SI unit the angular acceleration has unit of-
    (*a*) $Nmkg^{-1}$ (*b*) ms^{-2}
    (*c*) $rad.s^{-2}$ (*d*) Nkg^{-1}

13. The angular frequency is measured in rad s^{-1}. Its exponent in length are:
    (*a*) – 2 (*b*) –1
    (*c*) 0 (*d*) 2

14. $[M\ L\ T^{-1}]$ are the dimensions of-
    (*a*) power (*b*) momentum
    (*c*) force (*d*) couple

15. What are the dimensions of Boltzmann's constant?
    (*a*) $MLT^{-2}K^{-1}$ (*b*) $ML^2T^{-2}K^{-1}$
    (*c*) M^0LT^{-2} (*d*) $M^0L^2T^{-2}K^{-1}$

16. A pair of physical quantities having the same dimensional formula is:
    (a) angular momentum and torque
    (b) torque and energy
    (c) force and power
    (d) power and angular momentum

17. Which one of the following has the dimensions of $ML^{-1}T^{-2}$?
    (*a*) torque (*b*) surface tension
    (*c*) viscosity (*d*) stress

Principle of Homogeneity of Dimension

18. Force F is given in terms of time t and distance x by F = A sin C t + B cos D x Then the dimensions of $\frac{A}{B}$ and $\frac{C}{D}$ are given by
    (a) MLT^{-2}, $M^0L^0T^{-1}$
    (b) MLT^{-2}, $M^0L^{-1}T^0$
    (c) $M^0L^0T^0$, $M^0L^1T^{-1}$
    (d) $M^0L^1T^{-1}$, $M^0L^0T^0$

19. $\int \frac{xdx}{\sqrt{2ax - x^2}} = a^n \sin^{-1}\left[\frac{x}{a} - 1\right]$. The value of n is:
    You may use dimensional analysis to solve the problem.
    (a) 0
    (b) –1
    (c) 1
    (d) None of these

20. The equation for the velocity of sound in a gas states that $v = \sqrt{\gamma k_b \frac{T}{m}}$. Velocity v is measured in m/s. γ is a dimensionless constant, T is temperature in kelvin (K), and m is mass in kg. What are the units for the Boltzmann constant, k_b ?

(*a*) $kg \cdot m^2 \cdot s^{-2} \cdot K^{-1}$ (*b*) $kg \cdot m^2 \cdot s^2 \cdot K$
(*c*) $kg \cdot m/s \cdot K^{-2}$ (*d*) $kg \cdot m^2 \cdot s^{-2} \cdot K$

21. A wave is represented by
$y = a \sin (At - Bx + C)$
where A, B, C are constants and t is in seconds & x is in metre. The Dimensions of A, B, C are-

(*a*) $T^{-1}, L, M^0L^0T^0$ (*b*) $T^{-1}, L^{-1}, M^0L^0T^0$
(*c*) T, L, M (*d*) T^{-1}, L^{-1}, M^{-1}

22. If $v = \sqrt{\frac{\gamma p}{\rho}}$, then the dimensions of γ are (p is pressure, ρ is density and v is speed of sound has their usual dimension) -

(*a*) $M^0L^0T^0$ (*b*) $M^0L^0T^{-1}$
(*c*) $M^1L^0T^0$ (*d*) $M^0L^1T^0$

23. Consider the equation $\frac{d}{dt}\left[\int \vec{F} \cdot d\vec{s}\right] = A\left[\vec{F} \cdot \vec{P}\right]$ Then dimension of A will be (where $F \equiv$ force, ds $\equiv$ small displacement, t $\equiv$ time and $P \equiv$ linear momentum).

(*a*) $M^oL^oT^o$ (*b*) $M^1L^oT^o$
(*c*) $M^{-1}L^oT^o$ (*d*) $M^oL^oT^{-1}$

Application of Dimensional Analysis: Deriving New Relation

24. The velocity of water waves may depend on their wavelength λ, the density of water ρ and the acceleration due to gravity g. The method of dimensions gives the relation between these quantities aswhere k is a dimensionless constant

(*a*) $v^2 = k\lambda^{-1} g^{-1} \rho^{-1}$ (*b*) $v^2 = k g \lambda$
(*c*) $v^2 = k g \lambda \rho$ (*d*) $v^2 = k \lambda^3 g^{-1} \rho^{-1}$

25. Force applied by water stream depends on density of water (ρ), velocity of the stream (v) and cross–sectional area of the stream (*a*). The expression of the force should be

(α) ρAv (*b*) ρAv^2 (*c*) $\rho^2 Av$ (*d*) $\rho A^2 v$

Application of Dimensional Analysis: To Convert from one System of Unit

26. One watt-hour is equivalent to

(*a*) 6.3×10^3 Joule (*b*) 6.3×10^{-7} Joule
(*c*) 3.6×10^3 Joule (*d*) 3.6×10^{-3} Joule

27. The pressure of 10^6 dyne/cm² is equivalent to

(*a*) 10^5 N/m² (*b*) 10^6 N/m² (*c*) 10^7 N/m² (*d*) 10^8 N/m²

28. $\rho = 2$ g/cm³ convert it into MKS system-

(*a*) $2 \times 10^{-3} \frac{kg}{m^3}$ (*b*) $2 \times 10^3 \frac{kg}{m^3}$
(*c*) $4 \times 10^3 \frac{kg}{m^3}$ (*d*) $2 \times 10^6 \frac{kg}{m^3}$

29. The density of mercury is 13600 kg m^{-3}. Its value of CGS system will be:

(*a*) 13.6 g cm^{-3} (*b*) 1360 g cm^{-3}
(*c*) 136 g cm^{-3} (*d*) 1.36 g cm^{-3}

ERRORS IN MEASUREMENT

30. Which of the following measurements is most accurate ?

(*a*) 9×10^{-2} m (*b*) 90×10^{-3} m
(*c*) 900×10^{-4} m (*d*) 0.090 m

31. A system takes 70.40 second to complete 20 oscillations. The time period of the system is–

(*a*) 3.52 s (*b*) 35.2×10 s
(*c*) 3.520 s (*d*) 3.5200 s

32. The percentage error in the measurement of mass and speed are 1% and 2% respectively. What is the percentage error in kinetic energy–

(*a*) 5% (*b*) 2.5% (*c*) 3% (*d*) 1.5%

33. Number 15462 when rounded off to numbers to three significant digits will be-

(*a*) 15500 (*b*) 155
(*c*) 1546 (*d*) 150

34. Value of expression $\frac{25.2 \times 1374}{33.3}$ will be.

(All the digits in this expression are significant.)

(*a*) 1040 (*b*) 1039 (*c*) 1038 (*d*) 1041

35. Value of 24.36 + 0.0623 + 256.2 will be-

(*a*) 280.6 (*b*) 280.8 (*c*) 280.7 (*d*) 280.6224

36. The percentage errors in the measurement of mass and speed are 2% and 3% respectively. How much will be the maximum error in the estimation of the kinetic energy obtained by measuring mass and speed

(*a*) 11% (*b*) 8% (*c*) 5% (*d*) 1%

37. The random error in the arithmetic mean of 100 observations is x; then random error in the arithmetic mean of 400 observations would be

(*a*) $4x$ (*b*) $\frac{1}{4}x$

(*c*) $2x$ (*d*) $\frac{1}{2}x$

38. What is the number of significant figures in 0.310×10^3

(*a*) 2 (*b*) 3 (*c*) 4 (*d*) 6

39. Error in the measurement of radius of a sphere is 1%. The error in the calculated value of its volume is

(*a*) 1% (*b*) 3% (*c*) 5% (*d*) 7%

40. The mean time period of *second*'s pendulum is 2.00*s* and mean absolute error in the time period is 0.05*s*. To express maximum estimate of error, the time period should be written as

(*a*) $(2.00 \pm 0.01)\,s$ (*b*) $(2.00 + 0.025)\,s$

(*c*) $(2.00 \pm 0.05)\,s$ (*d*) $(2.00 \pm 0.10)\,s$

41. The unit of percentage error is

(a) Same as that of physical quantity

(b) Different from that of physical quantity

(c) Percentage error is unit less

(d) Errors have got their own units which are different from that of physical quantity measured

42. The decimal equivalent of 1/20 upto three significant figures is

(*a*) 0.0500 (*b*) 0.05000 (*c*) 0.0050 (*d*) 5.0×10^{-2}

43. Accuracy of measurement is determined by

(*a*) Absolute error (*b*) Percentage error

(*c*) Both (*a*) and (*b*) (*d*) None of these

44. A thin copper wire of length *l metre* increases in length by 2% when heated through 10ºC. What is the percentage increase in area when a square copper sheet of length *l metre* is heated through 10º*C*

(*a*) 4% (*b*) 8% (*c*) 16% (*d*) 32 %

45. In a vernier callipers, ten smallest divisions of the vernier scale are equal to nine smallest division on the main scale. If the smallest division on the main scale is half millimeter, then the vernier constant is–

(*a*) 0.5 mm (*b*) 0.1 mm (*c*) 0.05 mm (*d*) 0.005 mm

46. A vernier calliper has 20 divisions on the vernier scale, which coincide with 19 on the main scale. The least count of the instrument is 0.1 mm. The main scale divisions are of–

(*a*) 0.5 mm (*b*) 1mm

(*c*) 2mm (*d*) 1/4 mm

47. A vernier callipers having 1 main scale division = 0.1 cm is designed to have a least count of 0.02 cm. If n be the number of divisions on vernier scale and m be the length of vernier scale, then

(*a*) n = 10, m = 0.5 cm (*b*) n = 9, m = 0.4 cm

(*c*) n = 10, m = 0.8 cm (*d*) n = 10, m = 0.2 cm

Learning Plus

UNIT AND DIMENSIONS

1. Which of the following is not the unit of time

(*a*) solar day (*b*) parallactic second

(*c*) leap year (*d*) lunar month

2. The unit of impulse is the same as that of:

(a) moment force

(b) linear momentum

(c) rate of change of linear momentum

(d) force

3. Which of the following is not the unit of energy?

(a) watt-hour

(b) electron-volt

(c) N × m

(d) kg × m/sec^2

4. A dimensionless quantity:

(a) never has a unit

(b) always has a unit

(c) may have a unit

(d) does not exit

5. If a and b are two physical quantities having different dimensions then which of the following can denote a new physical quantity

(a) a + b

(b) a – b

(c) a/b

(d) $e^{a/b}$

6. The time dependence of a physical quantity ? $P = P_0 \exp(-\alpha t^2)$ where α is a constant and t is timeThe constant α

(a) will be dimensionless

(b) will have dimensions of T^{-2}

(c) will have dimensions as that of P

(d) will have dimensions equal to the dimension of P multiplied by T^{-2}

7. Which pair of following quantities has dimensions different from each other.

(a) Impulse and linear momentum

(b) Plank's constant and angular momentum

(c) Moment of inertia and moment of force

(d) Young's modulus and pressure

8. The product of energy and time is called action. The dimensional formula for action is same as that for

(*a*) power (*b*) angular energy

(*c*) force × velocity (*d*) impulse × distance

9. What is the physical quantity whose dimensions are $[M L^2 T^{-2}]$?

(*a*) kinetic energy (*b*) pressure

(*c*) momentum (*d*) power

10. If E, M, J and G denote energy, mass, angular momentum and gravitational constant respectively, then $\frac{EJ^2}{M^5G^2}$ has the dimensions of

(*a*) length (*b*) angle (*c*) mass (*d*) time

11. The position of a particle at time 't' is given by the relation $x(t) = \frac{V_0}{\alpha}[1 - e^{-\alpha t}]$ where V_0 is a constant and $\alpha > 0$. The dimensions of V_0 and α are respectively.

(*a*) $M^0L^1T^0$ and T^{-1} (*b*) $M^0L^1T^0$ and T^{-2}

(*c*) $M^0L^1T^{-1}$ and T^{-1} (*d*) $M^0L^1T^{-1}$ and T^{-2}

12. If force (F) is given by $F = Pt^{-1} + \alpha t$, where t is time. The unit of P is same as that of

(*a*) velocity (*b*) displacement

(*c*) acceleration (*d*) momentum

13. When a wave traverses a medium, the displacement of a particle located at x at time t is given by y = a sin (bt – cx) where a, b and c are constants of the wave. The dimensions of b are the same as those of

(*a*) wave velocity (*b*) amplitude

(*c*) wavelength (*d*) wave frequency

14. In a book, the answer for a particular question is expressed as $b = \frac{ma}{k}\left[\sqrt{1+\frac{2kl}{ma}}\right]$ here m represents mass, a represents accelerations, *l* represents length. The unit of b should be

(*a*) m/s (*b*) m/s^2

(*c*) meter (*d*) /sec

15. $\alpha = \frac{F}{V^2}\sin(\beta t)$ (here V = velocity, F = force, t = time) : Find the dimension of α and β -

(*a*) $\alpha = [M^1L^1T^0]$, $\beta = [T^{-1}]$

(*b*) $\alpha = [M^1L^1T^{-1}]$, $\beta = [T^1]$

(*c*) $\alpha = [M^1L^1T^{-1}]$, $\beta = [T^{-1}]$

(*d*) $\alpha = [M^1L^{-1}T^0]$, $\beta = [T^{-1}]$

16. If force, acceleration and time are taken as fundamental quantities, then the dimensions of length will be:

(*a*) FT^2 (*b*) $F^{-1} A^2 T^{-1}$ (*c*) FA^2T (*d*) AT^2

17. If area (*A*) velocity (v) and density (ρ) are base units, then the dimensional formula of force can be represented as

(*a*) $Av\rho$ (*b*) $Av^2\rho$

(*c*) $Av\rho^2$ (*d*) $A^2v\rho$

18. The velocity of a freely falling body changes as $g^p h^q$ where g is acceleration due to gravity and h is the height. The values of p and q are:

(*a*) $1, \frac{1}{2}$ (*b*) $\frac{1}{2}, \frac{1}{2}$

(*c*) $\frac{1}{2}, 1$ (*d*) 1, 1

19. If the unit of length is micrometer and the unit of time is microsecond, the unit of velcoity will be:

(*a*) 100 m/s (*b*) 10 m/s

(*c*) micrometers (*d*) m/s

20. In a certain system of units, 1 unit of time is 5 sec, 1 unit of mass is 20 kg and unit of length is 10m. In this system, one unit of power will correspond to

(*a*) 16 watts (*b*) 1/16 watts

(*c*) 25 watts (*d*) none of these

21. If the unit of force is 1 kilonewton, the length is 1 km and time is 100 second, what will be the unit of mass:

(*a*) 1000 kg (*b*) 10 kg

(*c*) 10000 kg (*d*) 100 kg

22. The units of length, velocity and force are doubled. Which of the following is the correct change in the other units?

(a) unit of time is doubled

(b) unit of mass is doubled

(c) unit of momentum is doubled

(d) unit of energy is doubled

23. If the units of force and that of length are doubled, the unit of energy will be:

(*a*) 1/4 times (*b*) 1/2 times

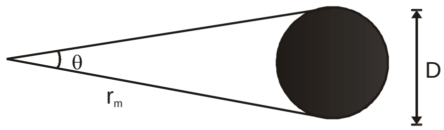
(*c*) 2 times (*d*) 4 times

24. If the units of M, L are doubled then the unit of kinetic energy will become

(*a*) 2 times (*b*) 4 times

(*c*) 8 times (*d*) 16 times

25. The angle subtended by the moon's diameter at a point on the earth is about 0.50°. Use this and the act that the moon is about 384000 km away to find the approximate diameter of the moon.



(*a*) 192000 km (*b*) 3350 km
(*c*) 1600 km (*d*) 1920 km

ERRORS IN MEASUREMENT

26. The length of a rectangular plate is measured by a meter scale and is found to be 10.0 cm. Its width is measured by vernier callipers as 1.00 cm. The least count of the meter scale and vernier callipers are 0.1 cm and 0.01 cm respectively (Obviously). Maximum permissible error in area measurement is -

(*a*) $\pm 0.2\ cm^2$ (*b*) $\pm 0.1\ cm^2$
(*c*) $\pm 0.3\ cm^2$ (*d*) Zero

27. For a cubical block, error in measurement of sides is $\pm$ 1% and error in measurement of mass is $\pm$ 2%, then maximum possible error in density is -

(*a*) 1% (*b*) 5%
(*c*) 3% (*d*) 7%

28. To estimate 'g' (from $g = 4\pi^2 \frac{L}{T^2}$), error in measurement of L is $\pm$ 2% and error in measurement of T is $\pm$ 3%. The error in estimated 'g' will be -

(*a*) $\pm$8% (*b*) $\pm$6%
(*c*) $\pm$3% (*d*) $\pm$5%

29. The least count of a stop watch is 0.2 second. The time of 20 oscillations of a pendulum is measured to be 25 seconds. The percentage error in the time period is

(*a*) 16% (*b*) 0.8 %
(*c*) 1.8 % (*d*) 8 %

30. The dimensions of a rectangular block measured with a vernier callipers having least count of 0.1 mm is 5 mm × 10 mm × 5 mm. The maximum percentage error in measurement of volume of the block is

(*a*) 5 % (*b*) 10 %
(*c*) 15 % (*d*) 20 %

31. An experiment measures quantities x, y, z and then t is calculated from the data as $t = \frac{xy^2}{z^3}$. If percentage errors in x, y and z are respectively 1%, 3%, 2%, then percentage error in t is :

(*a*) 10 % (*b*) 4 %
(*c*) 7 % (*d*) 13 %

32. The external and internal diameters of a hollow cylinder are measured to be (4.23 ± 0.01) cm and (3.89 ± 0.01) cm. The thickness of the wall of the cylinder is

(*a*) (0.34 ± 0.02) cm
(*b*) (0.17 ± 0.02) cm
(*c*) (0.17 ± 0.01) cm
(*d*) (0.34 ± 0.01) cm

33. The mass of a ball is 1.76 kg. The mass of 25 such balls is

(*a*) 0.44×10^3 kg (*b*) 44.0 kg
(*c*) 44 kg (*d*) 44.00 kg

34. Two resistors R_1 (24 ± 0.5) Ω and R_2 (8 ± 0.3) Ω are joined in series. The equivalent resistance is

(*a*) 32 ± 0.33 Ω (*b*) 32 ± 0.8 Ω
(*c*) 32 ± 0.2 Ω (*d*) 32 ± 0.5 Ω

35. The pitch of a screw gauge is 0.5 mm and there are 100 divisions on its circular scale. The instrument reads +2 divisions when nothing is put in-between its jaws. In measuring the diameter of a wire, there are 8 divisions on the main scale and 83rd division coincides with the reference line. Then the diameter of the wire is

(*a*) 4.05 mm (*b*) 4.405 mm
(*c*) 3.05 mm (*d*) 1.25 mm

36. The pitch of a screw gauge having 50 divisions on its circular scale is 1 mm. When the two jaws of the screw gauge are in contact with each other, the zero of the circular scale lies 6 division below the line of graduation. When a wire is placed between the jaws, 3 linear scale divisions are clearly visible while 31st division on the circular scale coincide with the reference line. The diameter of the wire is:

(*a*) 3.62 mm (*b*) 3.50 mm
(*c*) 3.5 mm (*d*) 3.74 mm

37. The smallest division on the main scale of a vernier callipers is 1 mm, and 10 vernier divisions coincide with 9 main scale divisions. While measuring the diameter of a sphere, the zero mark of the vernier scale lies between 2.0 and 2.1 cm and the fifth division of the vernier scale coincide with a scale division. Then diameter of the sphere is

(*a*) 2.05 cm (*b*) 3.05 cm
(*c*) 2.50 cm (*d*) None of these

Advanced Level Multiconcept Questions

JEE-ADVANCED
MCQ/COMPREHENSION/MATCHING/NUMERICAL

1. Choose the correct statement(s):
   (a) All quantities may be represented dimensionally in terms of the base quantities.
   (b) A base quantity cannot be represented dimensionally in terms of the rest of the base quantities.
   (c) The dimension of a base quantity in other base quantities is always zero.
   (d) The dimension of a derived quantity is never zero in any base quantity.

2. Choose the correct statement(s):
   (a) A dimensionally correct equation may be correct.
   (b) A dimensionally correct equation may be incorrect.
   (c) A dimensionally incorrect equation may be correct.
   (d) A dimensionally incorrect equation must be incorrect.

3. The dimensions $ML^{-1}T^{-2}$ may correspond to
   (a) work done by a force
   (b) linear momentum
   (c) pressure
   (d) energy per unit volume

Comprehension Type Questions – 1 (No. 4 to 6)

Let us consider a particle P where is moving straight on the X-axis. We also know that the rate of change of its position is given by $\frac{dx}{dt}$; where x is its separation from the origin and t is time. This term $\frac{dx}{dt}$ is called the velocity of particle (v). Further the second derivation of x, w.r.t. time is called acceleration (*a*) or rate of change of velocity and represented by $\frac{d^2x}{dt^2}$ or $\frac{dv}{dt}$. If the acceleration of this particle is found to depend upon time as follows

$a = At + Bt^2 + \frac{Ct}{D+t^2}$ then-

4. The dimensions of A are -
   (a) LT^{-2} (*b*) LT^{-3}
   (*c*) LT^3 (*d*) L^2T^3

5. The dimensions of B are -
   (a) LT^{-4} (*b*) L^2T^{-3}
   (*c*) LT^4 (*d*) LT^{-2}

6. The dimensions of C are -
   (a) L^2T^{-2} (*b*) LT^{-2}
   (*c*) LT^{-1} (*d*) T^2

Comprehension Type Questions – 2 (No. 7 to 9)

According to coulombs law of electrostatics there is a force between two charged particles q_1 & q_2 separated by a distance r such that $F \propto q_1$, $F \propto q_2$ & $F \propto \frac{1}{r^2}$; combining all three we get $F \propto \frac{q_1q_2}{r^2}$ or $F = \frac{kq_1q_2}{r^2}$, where k is a constant which depends on the medium and is given by $1/4\pi\varepsilon_0\varepsilon_r$ where ε_0 is absolute permittivity & ε_r is relative permittivity.

But in case of protons of a nucleus there exists another force called nuclear force; which is much higher in magnitude in comparison to electrostatic force and is given by $F = \frac{Ce^{-kr}}{r^2}$.

7. What are the dimensions of C -
   (*a*) $M^2L^3T^{-1}$ (*b*) ML^3T^{-3}
   (*c*) ML^3T^{-2} (*d*) ML^2T^{-3}

8. What are the dimensions of k –
   (*a*) L (*b*) L^2
   (*c*) L^{-3} (*d*) L^{-1}

9. What are the SI units of C -
   (*a*) Nm^{-2} (*b*) Nm^2
   (*c*) Nm^{-3} (*d*) Nm

10. Match the following columns

Physical quantity	Dimension	Unit
(a) Gravitational constant 'G'	(P) $M^1L^1T^{-1}$	(*a*) N.m
(b) Torque	(Q) $M^{-1}L^3T^{-2}$	(b) N.s
(c) Momentum	(R) $M^1L^{-1}T^{-2}$	(c) Nm^2/kg^2
(d) Pressure	(S) $M^1L^2T^{-2}$	(d) pascal

11. **Match the following:**

Physical quantity	**Dimension**	**Unit**
(i) Stefan's constant 'σ'	(P) $M^1L^1T^{-2}A^{-2}$	(*a*) W/m^2
(ii) Wien's constant 'b'	(Q) $M^1L^oT^{-3}K^{-4}$	(*b*) K.m.
(iii) Coefficient of viscosity 'η'	(R) $M^1L^oT^{-3}$	(*c*) tesla .m/A
(iv) Emissive power of radiation (Intensity emitted)	(S) $M^oL^1T^oK^1$	(*d*) $W/m^2.K^4$
(v) Mutual inductance 'M'	(T) $M^1L^2T^{-2}A^{-2}$	(e) poise
(vi) Magnetic permeability 'μ_0'	(U) $M^1L^{-1}T^{-1}$	(f) henry

NUMERICAL VALUE BASED

12. Number of significant figures in 0.007 m^2 .

13. Number of significant figures in 2.64×10^{24} kg

14. Number of significant figures in 6.032 N m^{-2}

15. The velocity of sound in a gas depends on its pressure and density. The relation between velocity, pressure and density is given by $V = Kp^a D^b$ then (a + b) is

16. A gas bubble, from an explosion under water, oscillates with a period proportional to $P^a d^b E^c$. Where P is the static pressure, d is the density and E is the total energy of the explosion. Find the values of a + b + c

17. The pitch of a screw gauge is 1 mm and there are 100 divisions on the circular scale. While measuring the diameter of a wire, the linear scale reads 1 mm and 47th division on the circular scale coincides with the reference line. The length of the wire is 5.6 cm. Find the curved surface area (in cm^2) of the wire in two number of significant figures.

18. The density of a cube is measured by measuring its mass and the length of its sides. If the maximum errors in the measurement of mass and length are 3% and 2% respectively, then the maximum error in the measurement of density is.

19. The length of the string of a simple pendulum is measured with a metre scale to be 90.0 cm. The radius of the bob plus the length of the hook is calculated to be 2.13 cm using measurements with a slide callipers. What is the effective length of the pendulum? (This effective length is defined as the distance between the point of suspension and the center of the bob).

JEE Mains & Advanced Past Years Questions

JEE-MAIN

1. A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90 s, 91 s, 95 s and 92 s,. If the minimum division in the measuring clock is 1 s, then the reported mean time should be: **[*JEE Main-2016*]**

(*a*) 92 ± 1.5 s (*b*) 92 ± 5.0 s
(*c*) 92 ± 1.8 s (*d*) 92 ± 3 s

2. A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of thin sheet of Aluminium. Before starting the measurement, it is found that when the two jaws of the screw gauge are brought in contact, the 45th division coincides with the main scale line and that the zero of the main scale is barely visible. What is the thickness of the sheet if the main scale reading is 0.5 mm and the 25th division coincides with the main scale line? **[*JEE Main-2016*]**

(*a*) 0.75 mm (*b*) 0.80 mm
(*c*) 0.70 mm (*d*) 0.50 mm

3. The following observations were taken for determining surface tension T of water by capillary method :
Diameter of capilary, $D = 1.25 \times 10^{-2}$ m
rise of water, $h = 1.45 \times 10^{-2}$ m
Using $g = 9.80\ m/s^2$ and the simplified relation

$T = \frac{rhg}{2} \times 10^3$ N/m , the possible error in surface tension is closest to : **[*JEE Main-2017*]**

(*a*) 2.4% (*b*) 10% (*c*) 0.15% (*d*) 1.5%

4. The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is: **[*JEE Main-2018*]**

(*a*) 3.5 % (*b*) 4.5 % (*c*) 6 % (*d*) 2.5 %

5. If speed (V), acceleration (A) and force (F) are considered as fundamental units, the dimension of Young's modulus will be:

[JEE Main-2019 (January)]

(a) $V^{-2}A^2F^{-2}$ (b) $V^{-2}A^2F^2$
(c) $V^{-4}A^{-2}F$ (d) $V^{-4}A^2F$

6. The density of a material in SI units is 128 kg m^{-3}. In certain units in which the unit of length is 25 cm and the unit of mass 50 g, the numerical value of density of the material is: **[JEE Main-2019 (January)]**

(a) 40 (b) 16 (c) 640 (d) 410

7. Expression for time in terms of G (universal gravitational constant), h (Planck constant) and c (speed of light) is proportional to:

[JEE Main-2019 (January)]

(a) $\sqrt{\frac{hc^5}{G}}$ (b) $\sqrt{\frac{c^3}{Gh}}$ (c) $\sqrt{\frac{Gh}{c^5}}$ (d) $\sqrt{\frac{Gh}{c^3}}$

8. Let L, R, C and V represent inductance, resistance, capacitance and voltage, respectively. The dimension of $\frac{L}{RCV}$ in SI units will be:

[JEE Main-2019 (January)]

(a) $[LA^{-2}]$ (b) $[A^{-1}]$ (c) $[LTA]$ (d) $[LT^2]$

9. In SI units, the dimension of $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ is

[JEE Main-2019 (April)]

(a) $A^{-1}TML^3$ (b) $A^2T^3M^{-1}L^{-2}$
(c) $AT^2M^{-1}L^{-1}$ (d) $AT^{-3}ML^{3/2}$

10. In the formula $X = 5YZ^2$, X and Z have dimensions of capacitance and magnetic field, respectively. What are the dimensions of Y in SI units?

[JEE Main-2019 (April)]

(a) $[M^{-2}L^{-2}T^6A^3]$ (b) $[M^{-1}L^{-2}T^4A^2]$
(c) $[M^{-3}L^{-2}T^8A^4]$ (d) $[M^{-2}L^0T^{-4}A^{-2}]$

11. If surface tension (S), Moment of inertia (I) and Planck's constnat (h), were to be taken as the fundamental units, the dimensional formula for linear momentum would be:

[JEE Main-2019 (April)]

(a) $S^{3/2}I^{1/2}h^0$ (b) $S^{1/2}I^{1/2}h^0$
(c) $S^{1/2}I^{1/2}h^{-1}$ (d) $S^{1/2}I^{3/2}h^{-1}$

12. Which of the following combination has the dimension of electrical resistance (ε_0 is the permittivity of vacuum and μ_0 is the permeability of vacuum) ?

[JEE Main-2019 (April)]

(a) $\sqrt{\frac{\varepsilon_0}{\mu_0}}$ (b) $\frac{\mu_0}{\varepsilon_0}$ (c) $\sqrt{\frac{\mu_0}{\varepsilon_0}}$ (d) $\frac{\varepsilon_0}{\mu_0}$

13. The pitch and the number of divisions, on the circular scale, for a given screw gauge are 0.5 mm and 100 respectively. When the screw gauge is fully tightened without any object, the zero of its circular scale lies 3 divisions below the mean line. The readings of the main scale and the circular scale for a thin sheet, are 5.5 mm and 48 respectively, the thickness of this sheet is

[JEE Main-2019 (January)]

(a) 5.755 mm (b) 5.950 mm
(c) 5.725 mm (d) 5.740 mm

14. The diameter and height of a cylinder are measured by a meter scale to be 12.6±0.1 cm and 34.2 ± 0.1 cm respectively. What will be the value of its volume in appropriate significant figures?

[JEE Main-2019 (January)]

(a) $4264 \pm 81\ cm^3$ (b) $4264 \pm 81.0\ cm^3$
(c) $4260 \pm 80\ cm^3$ (d) $4300 \pm 80\ cm^3$

15. The least count of the main scale of a screw gauge is 1 mm. The minimum number of divisions on its circular scale required to measure 5 μm diameter of a wire is:

[JEE Main-2019 (January)]

(a) 50 (b) 200 (c) 100 (d) 500

16. The area of a square is 5.29 cm^2. The area of 7 such squares taking into account the significant figures is

[JEE Main-2019 (April)]

(a) 37 cm^2 (b) 37.0 cm^2
(c) 37.03 cm^2 (d) 37.030 cm^2

17. In the density measurement of a cube, the mass and edge length are measured as (10.00 ± 0.10) kg and (0.10 ± 0.01) m, respectively. The error in the measurement of density is:

[JEE Main-2019 (April)]

(a) 0.10 kg/m^3 (b) 0.31 kg/m^3
(c) 0.07 kg/m^3 (d) 0.01 kg/m^3

18. The dimensions of $\frac{B^2}{2\mu_0}$, where B is magnetic field and μ_0 is the magnetic permeability of vacuum, is

(a) MLT^{-2} (b) $ML^{-1}T^{-2}$
(c) ML^2T^{-1} (d) ML^2T^{-2}

19. A quantity f is given by $f = \sqrt{\frac{hc^5}{G}}$ where c is speed of light, G universal gravitational constant and h is the Planck's constant. Dimension of f is that of :

[JEE Main-2020 (January)]

(a) volume (b) energy
(c) momentum (d) area

20. If momentum (P), area (A) and time (T) are taken to be the fundamental quantities then the dimensional formula for energy is **[*JEE Main-2020* (*September*)]**

(a) $\left[P^{\frac{1}{2}}AT^{-1}\right]$ (b) $[P^2AT^{-2}]$

(c) $\left[PA^{\frac{1}{2}}T^{-1}\right]$ (b) $[PA^{-1}T^{-2}]$

21. If speed V, area A and force F are chosen as fundamental units, then the dimension of Young's modulus will be **[*JEE Main-2020* (*September*)]**

(a) $FA^{-1}V^0$ (c) FA^2V^{-1}

(b) FA^2V^{-2} (d) FA^2V^{-3}

22. Amount of solar energy received on the earth's surface per unit area per unit time is defined a solar constant. Dimension of solar constant is **[*JEE Main-2020* (*September*)]**

(a) ML^2T^{-2} (b) MLT^{-2}

(c) $M^2L^0T^{-1}$ (d) ML^0T^{-3}

23. A quantity x is given by (IFv^2/WL^4) in terms of moment of inertia I, force F, velocity v, work W and length L. The dimensional formula for x is same as that of **[*JEE Main-2020* (*September*)]**

(a) Coefficient of viscosity

(b) Force constant

(c) Energy density

(d) Planck's constant

24. Dimensional formula for thermal conductivity is (here K deontes the temperature) **[*JEE Main-2020* (*September*)]**

(a) $MLT^{-2}K^{-2}$ (b) $MLT^{-3}K^{-1}$

(c) $MLT^{-3}K$ (d) $MLT^{-2}K$

25. The quantities $x = \frac{1}{\sqrt{\mu_0\varepsilon_0}}$, $y = \frac{E}{B}$ and $z = \frac{I}{CR}$ are defined where C-capacitance, R-Resistance, l-length, E-Electric field, B-magnetic field and ε_0, μ_0- free space permittivity and permeability respectively. Then **[*JEE Main-2020* (*September*)]**

(a) Only x and y have the same dimension

(b) Only x and z have the same dimension

(c) x, y and z have the same dimension

(d) Only y and z have the same dimension

26. A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. The length of the pendulum is 25.0 cm and a stop watch with 1s resolution measures the time taken for 40 oscillations to be 50 s. The accuracy in g is : **[*JEE Main-2020* (*January*)]**

(a) 4.40% (b) 3.40%

(c) 2.40% (d) 5.40%

27. If the screw on a screw–gauge is given six rotations, it moves by 3mm on the main scale. If there are 50 divisions on the circular scale the least count of the screw gauge is: **[*JEE Main-2020* (*January*)]**

(a) 0.01 cm (b) 0.02 mm

(c) 0.001 mm (d) 0.001 cm

28. When the temperature of a metal wire is increased from 0°C to 10°C, its length increases by 0.02%. The percentage change in its mass density will be closest to **[*JEE Main-2020* (*September*)]**

(a) 2.3 (b) 0.06

(c) 0.8 (d) 0.008

29. The least count of the main scale of a vernier callipers is 1 mm. Its vernier scale is divided into 10 divisions and coincide with 9 divisions of the main scale. When jaws are touching each other, the 7th division of vernier scale coincides with a division of main scale and the zero of vernier scale is lying right side of the zero of main scale. When this vernier is used to measure length of a cylinder the zero of the vernier scale between 3.1 cm and 3.2 cm and 4 VSD coincides with a main scale division. The length of the cylinder is (VSD is vernier scale division) **[*JEE Main-2020* (*September*)]**

(a) 3.21 cm (b) 2.99 cm

(c) 3.07 cm (d) 3.2 cm

30. Using screw gauge of pitch 0.1 cm and 50 divisions on its circular scale, the thickness of an object is measured. It should correctly be recorded as **[*JEE Main-2020* (*September*)]**

(a) 2.124 cm (b) 2.123 cm

(c) 2.125 cm (d) 2.121 cm

31. When a diode is forward biased, it has a voltage drop of 0.5 V. The safe limit of current through the diode is 10 mA. If a battery of emf 1.5 V is used in the circuit, the value of minimum resistance to be connected in series with the diode so that the current does not exceed the safe limit is **[*JEE Main-2020* (*September*)]**

(a) 50 Ω (b) 200 Ω

(c) 300 Ω (d) 100 Ω

32. A physical quantity z depends on four observables a, b, c and d, as $\frac{a^a b^{\frac{2}{3}}}{\sqrt{c}\,d^3}$. The percentages of error in the measurement of a, b, c and d are 2%, 1.5%, 4% and 2.5% respectively. The percentage of error in z is

[*JEE Main-2020 (September)*]

(*a*) 13.5% (*b*) 14.5%
(*c*) 16.5% (*d*) 12.25%

33. A student measuring the diameter of a pencil of circular cross-section with the help of a vernier scale records the following four readings 5.50 mm, 5.55 mm, 5.45 mm; 5.65 mm. The average of these four readings is 5.5375 mm and the standard deviation of the data is 0.07395 mm. The average diameter of the pencil should therefore be recorded as **[*JEE Main-2020 (September)*]**

(*a*) (5.5375 ± 0.0739) mm (*b*) (5.54 ± 0.07) mm
(*c*) (5.538 ± 0.074) mm (*d*) (5.5375 ± 0.0740) mm

34. The density of a solid metal sphere is determined by measuring its mass and its diameter. The maximum error in the density of the sphere is $\left(\frac{x}{100}\right)$%. If the relative errors in measuring the mass and the diameter are 6.0% and 1.5% respectively, the value of x is _____.

[*JEE Main-2020 (September)*]

35. The vernier scale used for measurement has a positive zero error of 0.2 mm. If while taking a measurement it was noted that ' 0 ' on the vernier scale lies between 8.5cm and 8.6 cm, vernier coincidence is 6, then the correct value of measurement is cm. (least count $= 0.01\text{cm}$) **[*JEE Main-2021 (March)*]**

(*a*) 8.58cm (*b*) 8.54cm
(*c*) 8.56cm (*d*) 8.36cm

36. In order to determine the Young's Modulus of a wire of radius 0.2cm (measured using a scale of least count $= 0.001\text{cm}$) and length 1m (measured using a scale of least count $= 1\text{mm}$), a weight of mass 1kg (measured using a scale of least count $= 1\text{g}$) was hanged to get the elongation of 0.5cm (measured using a scale of least count 0.001cm). What will be the fractional error in the value of Young's Modulus determined by this experiment?

[*JEE Main-2021 (March)*]

(*a*) 0.14% (*b*) 9%
(*c*) 1.4% (*d*) 0.9%

37. One main scale division of a vernier callipers is 'a' cm and n^{th} division of the vernier scale coincide with $(n-1)^{th}$ division of the main scale. The least count of the callipers in mm is: **[*JEE Main-2021 (March)*]**

(*a*) $\frac{10a}{R}$ (*b*) $\frac{10ra}{(r-1)}$
(*c*) $\left(\frac{R-1}{10R}\right)a$ (*d*) $\frac{10a}{(r-1)}$

JEE-ADVANCED

1. In the determination of Young's modulus $\left(Y = \frac{4MLg}{\pi l d^2}\right)$ by using Searle's method, a wire of length L = 2 m and diameter d = 0.5 mm is used. For a load M = 2.5 kg, an extension l = 0.25 mm in the length of the wire is observed. Quantities d and l are measured using a screw gauge and a micrometer, respectively. They have the same pitch of 0.5 mm. The number of divisions on their circular scale is 100. The contributions to the maximum probable error of the Y measurement **[*IIT JEE-2012*]**

(*a*) due to the errors in the measurements of d and l are the same.
(b) due to the error in the measurement of d is twice that due to the error in the measurement of l
(c) due to the error in the measurement of l is twice that due to the error in the measurement of d.
(d) due to the error in the measurement of d is four time that due to the error in the measurement of l

2. Match List-I with List-II and select the correct answer using the codes given below the lists :

[*JEE Advanced-2013*]

	List-I		List-II
P.	Boltzmann constant	1.	$[ML^2T^{-1}]$
Q.	Coefficient of viscosity	2.	$[ML^{-1}T^{-1}]$
R.	Planck constant	3.	$[MLT^{-3}K^{-1}]$
S.	Thermal conductivity	4.	$[ML^2T^{-2}K^{-1}]$

Codes :

	P	Q	R	S
(*a*)	3	1	2	4
(*b*)	3	2	1	4
(*c*)	4	2	1	3
(*d*)	4	1	2	3

3. The diameter of a c ylinder is measured using a vernier callipers with no zero error. It is found that the zero of the vernier scale lies between 5.10 cm and 5.15 cm of the main scale. The vernier scale has 50 division equivalent to 2.45 cm. The 24^{th} division of the vernier scale exactly coincides with one of the main scale divisions. The diameter of the cylinder is :

[*JEE Advanced-2013*]

(*a*) 5.112 cm (*b*) 5.124 cm
(*c*) 5.136 cm (*d*) 5.148 cm

4. In an experiment to determine the acceleration due to gravity g, the formula used for the time period of a periodic motion is $T = 2\pi\sqrt{\frac{7(R-r)}{5g}}$. The values of R and R are measured to be (60 ± 1) mm and (10 ± 1) mm, respectively. In five successive measurements, the time period is found to be 0.52 s, 0.56s, 0.57s, 0.54s and 0.59 s. The least count of the watch used for the measurement of time period is 0.01 s. Which of the following statement(s) is (are) true? **[*JEE Advanced-2013*]**

(a) The error in the measurement of *r* is 10%
(b) The error in the measurement of *T* is 3.57%
(c) The error in the measurement of *T* is 2%
(d) The error in the determined value of g is 11%

5. Using the expression $2d \sin\theta = \lambda$, one calculates the values of d by measuring the corresponding angles θ in the range 0 to 90º. The wavelength λ is exactly knowns and the error in θ is constant for all values of As θ increases from 0º : **[*JEE Advanced-2013*]**

(a) the absolute error in d remains constant.
(b) the absolute error in d increases.
(c) the fractional error in d remains constant.
(d) the fractional error in d decreases.

6. To find the distance d over which a signal can be seen clearly in foggy conditions, a railways engineer uses dimensional analysis and assumes that the distance depends on the mass density ρ of the fog, intensity (power/area) S of the light from the signal and its frequency f. The engineer find that d is proportional to $S^{1/n}$. The value of n is:

[*JEE Advanced-2014*]

7. A length –scale (l) depends on the permittivity (ε) of a dielectric material, Boltzmann constant((k_B), the absolute temperature (T), the number per unit volume (n) of certain charged particles, and the charge (q) carried by each of the particles. Which of the following expression(s) for l is (are) dimensionally correct?

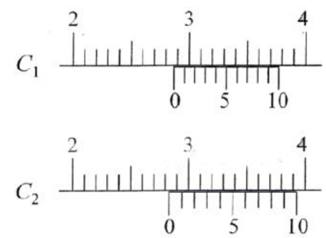
[*JEE Advanced-2016*]

(*a*) $l = \sqrt{\left(\frac{nq^2}{\varepsilon k_B T}\right)}$ (*b*) $l = \sqrt{\left(\frac{\varepsilon k_B T}{nq^2}\right)}$

(*c*) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{2/3} k_B T}\right)}$ (*d*) $l = \sqrt{\left(\frac{q^2}{\varepsilon n^{1/3} k_B T}\right)}$

8. There are two Vernier calipers both of which have 1 cm divided into 10 equal divisions on the main scale. The Vernier scale of one of the calipers (C_1) has 10 equal divisions that correspond to 9 main scale divisions. The Vernier scale of the other caliper (C_2) has 10 equal divisions that correspond to 11 main scale division. The readings of the two calipers are shown in the figure. The measured values (in cm) by calipers C_1 and C_2, respectively, are

[*JEE Advanced-2016*]



(*a*) 2.87 and 2.86 (*b*) 2.85 and 2.82
(*c*) 2.87 and 2.87 (*d*) 2.87 and 2.83

Comprehension – 1 (No. 9 and 10)

In electromagnetic theory, the electric and magnetic phenomena are related to each other. Therefore, the dimensions of electric and magnetic quantities must also be related to each other. In the questions below, [E] and [B] stand for dimensions of electric and magnetic fields respectively, while $[\epsilon_0]$ and $[\mu\ ]$ stand for dimensions of the permittivity and permeability of free space respectively. [L] and [T] are dimensions of length and time respectively. All the quantities are given in SI units.

[*JEE Advanced - 2018*]

9. The relation between [E] and [B] is -

(*a*) [E] = [B] [L] [T] (*b*) $[E] = [B] [L]^{-1} [T]$
(*c*) $[E] = [B] [L] [T]^{-1}$ (*d*) $[E] = [B] [L]^{-1} [T]^{-1}$

10. The relation between $[\epsilon_0]$ and $[\mu_0]$ is -

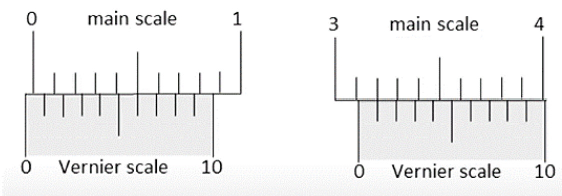
(*a*) $[\mu_0] = [\epsilon_0] [L]^2 [T]^{-2}$
(*b*) $[\mu_0] = [\epsilon_0] [L]^{-2} [T]^2$
(*c*) $[\mu_0] = [\epsilon_0]^{-1} [L]^2 [T]^{-2}$
(*d*) $[\mu_0] = [\epsilon_0]^{-1} [L]^{-2} [T]^2$

11. Let us consider a system of units in which mass and angu- lar momentum are dimensionless. If length has dimension of L, which of the following statement (s) is/are correct?

[*JEE Advanced - 2019*]

(a) The dimension of force is L^{-3}
(b) The dimension of energy is L^{-2}
(c) The dimension of power is L^{-5}
(d) The dimension of linear momentum is L^{-1}

12. The smallest division on the main scale of a Venire callipers is 0.1cm. Ten divisions of the Vernier scale correspond to nine divisions of the main scale. The figure below on the left shows the reading of this calliper with no gap between its two jaws. The figure on the right shows the reading with a solid sphere held between the jaws. The correct diameter of the sphere is **[*JEE Advanced-2021*]**



(*a*) 3.07cm (*b*) 3.11cm

(*c*) 3.15cm (*d*) 3.17cm

13. A physical quantity S is defined as $S = (\vec{E} \times \vec{B})/\mu_0$ where $\vec{E}$ is electric field, $\vec{B}$ is magnetic field and μ_0 is the permeability of free space. The dimensions of S are the same as the dimensions of which of the following quantity (ies) ? **[*JEE Advanced-2021*]**

(*a*) $\dfrac{\text{Energy}}{\text{charge} \times \text{current}}$

(*b*) $\dfrac{\text{Force}}{\text{Length} \times \text{Time}}$

(*c*) $\dfrac{\text{Energy}}{\text{Volume}}$

(*d*) $\dfrac{\text{Power}}{\text{Area}}$

ANSWER KEY

Topicwise Questions

1. (a)	**2.** (a)	**3.** (c)	**4.** (b)	**5.** (c)	**6.** (b)	**7.** (b)	**8.** (d)	**9.** (a)	**10.** (d)
11. (d)	**12.** (c)	**13.** (c)	**14.** (b)	**15.** (b)	**16.** (b)	**17.** (d)	**18.** (c)	**19.** (c)	**20.** (a)
21. (b)	**22.** (a)	**23.** (c)	**24.** (b)	**25.** (b)	**26.** (c)	**27.** (a)	**28.** (b)	**29.** (a)	**30.** (c)
31. (c)	**32.** (a)	**33.** (a)	**34.** (a)	**35.** (c)	**36.** (b)	**37.** (b)	**38.** (b)	**39.** (b)	**40.** (c)
41. (c)	**42.** (a)	**43.** (b)	**44.** (a)	**45.** (c)	**46.** (c)	**47.** (c)			

Learning Plus

1. (b)	**2.** (b)	**3.** (d)	**4.** (c)	**5.** (c)	**6.** (b)	**7.** (c)	**8.** (d)	**9.** (a)	**10.** (b)
11. (c)	**12.** (d)	**13.** (d)	**14.** (c)	**15.** (d)	**16.** (d)	**17.** (b)	**18.** (b)	**19.** (d)	**20.** (a)
21. (c)	**22.** (c)	**23.** (d)	**24.** (c)	**25.** (b)	**26.** (a)	**27.** (b)	**28.** (a)	**29.** (b)	**30.** (a)
31. (d)	**32.** (c)	**33.** (b)	**34.** (b)	**35.** (b)	**36.** (d)	**37.** (a)			

Advanced Level Multiconcept Questions

1. (a, b, c) **2.** (a, b, d) **3.** (c, d) **4.** (b) **5.** (a) **6.** (c) **7.** (c) **8.** (d) **9.** (b)

10. $(a) \to (\mathrm{Q}) \to (c), (b) \to (\mathrm{S}) \to (a), (c) \to (\mathrm{P}) \to (b), (d) \to (\mathrm{R}) \to (d)$

11. $(i) \to (\mathrm{Q}) \to (d), (ii) \to (\mathrm{S}) \to (b), (iii) \to (U) \to (e), (iv) \to (\mathrm{R}) \to (a), (v) \to (\mathrm{T}) \to (f), (vi) \to (\mathrm{P}) \to (c)$

12. [1] **13.** [3] **14.** [4] **15.** [1] **16.** [0] **17.** [2.6] **18.** [9] **19.** [92.1]

JEE Mains & Advanced Past Years Questions

JEE-MAIN

1. (a)	**2.** (b)	**3.** (d)	**4.** (b)	**5.** (d)	**6.** (a)	**7.** (c)	**8.** (b)	**9.** (b)	**10.** (c)
11. (b)	**12.** (c)	**13.** (c)	**14.** (c)	**15.** (b)	**16.** (c)	**17.** (Bonus)	**18.** (b)	**19.** (b)	**20.** (c)
21. (a)	**22.** (d)	**23.** (c)	**24.** (b)	**25.** (c)	**26.** (d)	**27.** (d)	**28.** (b)	**29.** (c)	**30.** (a)
31. (d)	**32.** (b)	**33.** (b)	**34.** [1050.00]	**35.** (b)	**36.** (c)	**37.** (a)			

JEE-ADVANCED

1. (a)	**2.** (c)	**3.** (b)	**4.** (a, b, d)	**5.** (d)	**6.** (c)	**7.** (b, d)	**8.** (d)	**9.** (c)	**10.** (d)
11. (a, b, d)	**12.** (c)	**13.** (b, d)							

1 Units and Measurements

Topicwise Questions

1. (*a*) It is obvious.
2. (*a*) Kilogram is not a physical quantity, its a unit.
3. (*c*) PARSEC is a unit of distance.
   It is used in astronomical science.
4. (*b*) System is NOT based on unit of mass, length and time alone,
   This system is based on all 7 Fundamental physical quantities and 2 supplementary physical quantities.
5. (*c*) S.I. unit of energy is Joule.
6. (*b*) SI unit of universal gravitational constant G is -

   We know $F = \frac{GM_1M_2}{R^2}$

   Here M_1 and M_2 are mass
   R = Distance between them M_1 and M_2
   F = Force

   $$G = \frac{FR^2}{M_1M_2} = \frac{N-m^2}{kg^2}$$

   So, Unit of G = $N–m^2\ kg^{-2}$
7. (*b*) Surface Tension (T) :-

   $$T = \frac{J}{A} = \frac{J}{m^2}$$

   So S.I. unit of surface tension is joule/m^{+2}
8. (*d*) Here ρ is specific resistance.

   $$R = \frac{\rho l}{A} \Rightarrow \text{ohm} = \frac{\rho m}{m^2} \qquad \Rightarrow \rho = \text{ohm} \times m$$

9. (*a*) Here i = current
   A = crossectional Area
   M = iA
   = Amp. m^2
10. (*d*) Unit of universal gas constant (R)
   PV = nRT P $\rightarrow$ Pressure
   V $\rightarrow$ Volume

   $R = \frac{PV}{nT}$ T $\rightarrow$ Temperature

   $= \frac{N/m^2 \times m^3}{mol. \times K}$ R $\rightarrow$ Univ. Gas. Const.

   n $\rightarrow$ No. of male

   $= \frac{N-m}{mol. \times K} = \text{Joule}\ K^{-1} mol^{-1}$

   {n – m = joule}
11. (*d*) Stefan-Constant(σ)
   Unit $\rightarrow$ w/m^2-k^4 = $wm^{-2}k^{-4}$
12. (*c*) S.I. unit of the angular acceleration is rad/s^2.
   α = angular velocity/time = rad/s^2 = rad.s^{-2}
13. (*c*) Angular Frequency (f) $= \frac{1}{T} = M^oL^oT^{-1}$

   So, here dimension in length is zero
14. (*b*) P = mvm $\rightarrow$ mass
   v $\rightarrow$ velocity
   Dimesion of [P] = [MLT^{-1}]
15. (*b*) Boltz mann's const. (k) $\rightarrow$ J $\rightarrow$ Joule
   K $\rightarrow$ Kelvin
   Unit $\rightarrow$ J/k

   Dimension $= \frac{M^1L^2T^{-2}}{K^1} = M^1L^2T^{-2}K^{-1}$
16. (*b*) Find out Dimension of each physical quantity in all options.
   AM = $Mvr^2 = ML^2T^{-1}$
   Dimension of Torque (τ)= $\vec{r} \times \vec{F}$ $\rightarrow$Force = MLT^{-2}
   (τ) = $L^1 \times M^1L^1T^{-2}$
   It is also a dimension of Energy. = ML^2T^{-2}
   Power = W/t = $ML^2T^{-2}/T = ML^2T^{-3}$

17. (*d*) Find dimension in all options.

Here stress = Force/Area

$= \frac{M^1L^1T^{-2}}{L^2}$

stress = $[M^1L^{-1}T^{-2}]$

18. (*c*) All the terms in the equation must have the dimension of force

$\therefore$ [A sin C t] = MLT^{-2}

$\Rightarrow$ [A] $[M^0L^0T^0] = MLT^{-2}$

$\Rightarrow$ [A] = MLT^{-2}

Similarly, [B] = MLT^{-2}

$\therefore \frac{[A]}{[B]} = M^oL^oT^o$

Again [Ct] = $M^oL^oT^o \Rightarrow [C] = T^{-1}$

$[Dx] = MLT^o \Rightarrow [D] = L^{-1}$

$\Rightarrow \frac{[C]}{[D]} = M^oL^1T^{-1}$.

19. (*c*) $\int \frac{dx}{\sqrt{2ax - x^2}} = a^n \sin^{-1}\left[\frac{x}{a} - 1\right]$.

L.H.S. is the dimensionless as denominator $2ax - x^2$ must have the dimension of $[x]^2$ ($\because$ we can add or substract only if quantities have same dimension)

$\therefore \left[\sqrt{2ax - x^2}\right] = [x]$

Also, dx has the dimension of [x]

$\therefore \frac{x\,dx}{\sqrt{2ax - x^2}}$ is having dimension L

Equating the dimension of L.H.S. & R.H.S. we have

$[a^n] = M^0L^1T^0$ { $\therefore \sin^{-1}\left(\frac{x}{a} - 1\right)$ must be dimensionless

$\therefore$ n = 1

20. (*a*)

21. (*b*) y = a sin(At – Bx + C)

Angle has no dimensions so

Dimensions of At = $M^0L^0T^0$

$\Rightarrow$ A = T^{-1}

Dimensions of Bx = $M^0L^0T^0$

$\Rightarrow$ B = L^{-1}

Dimensions of C = $M^0L^0T^0$

22. (*a*) Dimensions of $\sqrt{\frac{\gamma p}{\rho}}$ = Dimensions of v

$\gamma L^2T^{-2} = L^2T^{-2}$

$\gamma = M^0L^0T^0$

23. (*c*) $A = \frac{d\ work}{dt}\ \frac{1}{F} P$

$$[A] = \frac{[work]}{[time]\frac{[work]}{[displacement]} \times [P]}$$

$= \frac{L}{T} MLT^{-1} = \frac{1}{M}$

24. (*b*) $[v] = [k]\,[\lambda^a \rho^b g^c] \Rightarrow LT^{-1} = L^a M^b L^{-3b} L^c T^{-2c}$

$\Rightarrow LT^{-1} = M^b L^{a-3b+c} T^{-2c}$

$\Rightarrow$ a = ½, b = 0, c = ½

so, $v^2 = kg\lambda$

25. (*b*) It is obvious

26. (*c*) $P = \frac{W}{t}$

Watt = Joule/sec.

Joule = Watt-sec.

One watt-hour = 1 watt×60×60 sec

1 Hour=60×60sec. = 3600 watt-sec

= 3600 Joule

= 3.6×10^3 Joule

27. (*a*) Given

$P = 10^6$ dyne/cm^2

$n_1u_1 = n_2u_2$

$n_1\left[M_1^1L_1^{-1}T_1^{-2}\right] = 10^6\left[M_2^1L_2^{-1}T_2^{-2}\right]$

$n_1 = 10^6\left[\frac{M_2}{M_1}\right]^1\left[\frac{L_2}{L_1}\right]^{-1}\left[\frac{T_2}{T_1}\right]^{-2}$

$= 10^6\left[\frac{1}{1000}\right]^1\left[\frac{1}{100}\right]^{-1}$

$\Rightarrow 10^6 \times \frac{10^2}{10^3} = 10^5\ N/m^2$

28. (*b*) $\rho = 2g/cm^3$

$n_1u_1 = n_2u_2$

$n_1\left[M_1^1L_1^{-3}\right] = 2\left[M_2^1L_2^{-3}\right]$

$n_1 = 2\left[\frac{M_2}{M_1}\right]^1\left[\frac{L_2}{L_1}\right]^{-3}$

$= 2\left[\frac{10^{-3}}{1}\right]^1\left[\frac{10^{-2}}{1}\right]^{-3}$

= $2 \times 10^{-3} \times 10^6$

= 2×10^3 Kg/m^3

29. (*a*) $n_2 = 13600\left[\frac{M_1}{M_2}\right]^1\left[\frac{L_1}{L_2}\right]^{-3}$

$$= 13600\left[\frac{1000}{1}\right]^1\left[\frac{100}{1}\right]^{-3}$$

$n_2 = 13.6\ gcm^{-3}$

30. (*c*) Measurement 900×10^{-4} m is most accurate as significant figure is 3,

31. (*c*) 70.40s four significant figures.
Time period = 3.520 sec. (4 significant figure)

32. (*a*) $KE = \frac{1}{2}mv^2$

$$\frac{\Delta k}{k}\times 100 = 1\% + 2\times 2\% = 5\%$$

33. (*a*) The third significant digit is 4. This digit is to be rounded. The digit next to it is 6 which is greater than 5. The third digit should, therefore , be increased by 1. The digits to be dropped should be replaced by zeros because they appear to the left of the decimal. Thus, 15462 becomes 15500 on rounding to three significant digits.

34. (*a*) We have $\frac{25.2 \times 1374}{33.3} = 1039.7838$ .....

Out of the three numbers given in the expression 25.2 and 33.3 have 3 significant digits and 1374 has four. The answer should have three significant digits. Rounded 1039.7838 .... to three significant digits, it becomes 1040.

Thus , we write.

$$\frac{25.2 \times 1374}{33.3} = 1040.$$

35. (*c*) 24.36
0.0623
256.2

Now the first column where a doubtful digit occurs is the one just next to the decimal point (256.2). All digits right to this column must be dropped after proper rounding. The table is rewritten and added below

24.4
0.1
256.2
———
280.7 The sum is 280.7

36. (*b*) $\therefore E = \frac{1}{2}mv^2$

$\therefore$ % Error in K.E.
= % error in mass + 2 × % error in velocity
= 2 + 2 × 3 = 8 %

37. (*b*)

38. (*b*) Number of significant figures are 3, because 10^3 is decimal multiplier.

39. (*b*)

$\because V = \frac{4}{3}\pi r^3$

$\therefore$ % error is volume $= 3\times\%$ error in radius $= 3\times 1 = 3\%$

40. (*c*) Mean time period $T = 2.00$ *sec*
& Mean absolute error = $\Delta T = 0.05$ *sec*.
To express maximum estimate of error, the time period should be written as (2.00 ± 0.05) *sec*

41. (*c*)

42. (*a*) $\frac{1}{20} = 0.05$

$\therefore$ Decimal equivalent upto 3 significant figures is 0.0500

43. (*b*)

44. (*a*) Since percentage increase in length = 2 %
Hence, percentage increase in area of square sheet
$= 2\times 2\% = 4\%$

45. (*c*) 1 main scale div = 0.5 mm
10V = 9S

$$V = \frac{9}{10}S$$

$$S - V = S - \frac{9}{10}S = \frac{1}{10}S.$$

$$\therefore \text{Vernier constant} = \frac{0.5\text{ mm}}{10} = 0.05\text{ mm}$$

46. (c) $20V = 19s., V = \frac{19}{20}S$

$$S - V = S - \frac{19}{20}S \Rightarrow \text{vernier} = \frac{S}{20}$$

$$0.1\text{ mm} = \frac{S}{20}$$

$\therefore$ 1s = 20 × 0.1 mm = 2 mm.

47. (*c*) 1 VC = 1 MSD – VSD

$$1VC = 0.1\text{ cm} - \frac{n}{m}$$

$$0.02\text{ cm} = \frac{1}{10} - \frac{n}{m}$$

$$\frac{n}{m} = \frac{1}{10} - \frac{2}{100}$$

n = 10, m = 0.8 cm

1. (*b*) Solar day $\rightarrow$ Time far Earth to wake a complete rotation on its axis
   Parallactic second [1 Parsec] $\rightarrow$ It is a distance corresponding to a parallex of one second of arc.
   Leap year $\rightarrow$ A leap year is year (time) Containing one extra day.
   Lunar Month $\rightarrow$ A lunar month is the time between two identical view moons of full moons.
   1 Lunar month = 29.53059 days.
2. (*b*) Unit of impulse = $\Rightarrow$ Impulse = Force × time
   $$= kg\frac{m}{sec^2}sec = kg\frac{m}{sec} = mv$$
   The unit is same as the unit of linear momentum.
3. (*d*) Energy W = f × d = Nm
   W = eV = electron-volt W
   = p × t = Watt hour
   So, kg × m/sec^2 is not the unit of energy.
4. (*c*) Dimensionless quantity may have a unit
   Ex. Angle Unit $\rightarrow$ Radian
   Dimension $\rightarrow M^oL^oT^o$
5. (*c*) Only same physical quantities can be added or substracted,
   It's only multiply and divided only.
   So, a/b denote a new physical quantity.
6. (*c*) $P = P_o \, Exp(-\alpha t^2)$
   Here Exp $(-\alpha t^2)$ is a dimensionless
   So, dimension of $[\alpha t^2] = M^oL^oT^o$
   $$So, [\alpha] = \frac{M^oL^oT^o}{T^2}$$
   $[\alpha] = M^oL^oT^{-2}$
7. (*c*) By Checking the dimension in all options
   (*c*) Moment of Inertia = Mr^2
   $= M^1L^2T^o$
   Moment of force = r × F
   $= L^1 \times M^1L^1T^{-2}$
   $= M^1L^2T^{-2}$
8. (*d*) Action = Energy × Time = $M^1L^2T^{-2} \times T^1$
   $= M^1L^2T^{-1}$
   It is same as dimension of Impulse × distance
   $= MLT^{-1} \times L^1 = M^1L^2T^{-1}$

9. (*a*) $M^1L^2T^{-2}$ is a dimension of kinetic energy.

10. (*b*) $\frac{EJ^2}{M^5G^2}$ J=mvr, J = $[ML^2T^{-1}]$
   $= [M^0L^0T^0]$
   Dimension of Angle = $[M^0L^0T^0]$

11. (*c*) $x(t) = \frac{v_o}{\alpha}[1 - e^{-\alpha t}]$
   Dimension of v_o and α
   Here $e^{-\alpha t}$ is dimensionless so,
   $[\alpha][t] = M^oL^oT^o$
   $$[\alpha] = \frac{M^oL^oT^o}{T^1} = T^{-1}$$
   $[\alpha] = M^oL^oT^{-1}$
   Here1-$e^{-\alpha t}$ is a number
   $$[x(t)] = \frac{V_o}{\alpha}$$
   $[V_o] = [L^1][T^{-1}]$
   $[V_o] = M^oL^1T^{-1}$

12. (*d*) $F = Pt^{-1} + \alpha t$
   Here F and Pt^{-1} is a same
   Physical quantity
   $[F] = [Pt^{-1}]$
   $$[P] = \frac{[F]}{[t^-]} = [F \times t] = MLT^{-2} \times T = MLT^{-1}$$
   We find it is same as dimension of momentum $= MLT^{-1}$

13. (*d*) Y = a sin (bt – cx)
   Dimension of b
   Here bt is dimensionless
   $[bt] = M^oL^oT^o$
   $$[b] = \frac{M^oL^oT^o}{[T^1]} = M^oL^oT^{-1}$$
   It is a dimension of wave frequency.

14. (*c*) Here $\sqrt{1 + \frac{2kl}{ma}}$ is a number.
   It's a dimensionless quantity.
   $$\left[\frac{2kl}{ma}\right] = [M^oL^oT^o]$$
   $$[K] = \frac{[m][a]}{[l]}$$

$$= \frac{M^1L^1T^{-2}}{L^1} = M^1L^oT^{-2}$$

So dimession of [b] is

$$[b] = \left[\frac{ma}{K}\right] = \left[\frac{MLT^{-2}}{MT^{-2}}\right]$$

$[b] = L$

unit of b is metre

15. (*d*) $\alpha = \frac{F}{V^2}\sin(\beta t)$

Here sin (βt) is dimensionless.

$[\beta t] = M^oL^oT^o$

$$\beta = \frac{M^oL^oT^o}{T^1} = \left[T^{-1}\right]$$

$$[\alpha] = \left[\frac{F}{V^2}\right]$$

$$= \frac{M^1L^1T^{-2}}{[L^1T^{-1}]^2} = \frac{M^1L^1T^{-2}}{L^2T^{-2}}$$

$[\alpha] = [M^1L^{-1}T^o]$

16. (*d*) L α FAT

$L = K\,F^aA^bT^c$ .... (*a*)

$M^oL^1T^o = K[M^1L^1T^{-2}]\,[L^1T^{-2}]^b[T]^c$

$M^oL^1T^o = K[M^a]\,[L^{a+b}]\,[T^{-2a-2b+c}]$

By comparesion and solving we find

[a = 0] [b = 1] [c = 2]

Put these value in Equa. (*a*)

$[L = F^oA^1T^2]$

17. (*b*) F α Avρ

$F = KA^a\,v^b\,\rho^c$

$= K[L^2]^a\,[L^1T^{-1}]^b\,[M^1L^{-3}]^c$

$F = K[M^cL^{2a+b-3c}\,T^{-b}]$

$M^1L^1T^{-2} = K[M^c\,L^{2a+b-3c}T^{-b}]$

c = 1

$-2 = -b \Rightarrow b = 2$

and

2a + b – 3c = 1

$2a + 2 - 3 = 1 \Rightarrow a = 1$

So $F = A^1\,v^2\,q^1$

$\therefore$ $F = Av^2\rho$

18. (*b*) $V = g^p\,h^q$

$V = Kg^ph^q$

$[L^1T^{-1}] = [L^1T^{-2}]^p\,[L^1]^q$

$L^1T^{-1} = L^{p+q}\,T^{-2p}$

By comparing both sides

p + q = 1, –2p = –1

p = 1/2, q = 1/2

19. (*d*) Unit of length is micrometer

Unit of time is microsecond

$$\cdot\ \text{Velocity} = \frac{\text{Displacement}}{\text{Time taken}}$$

$$= \frac{10^{-6}\,m}{10^{-6}\,sec} = m/sec$$

20. (*a*) $n_1u_1 = n_1u_1$

$$n_1\left[M_1^1L_1^2T_1^{-3}\right] = 1\left[M_2^1L_2^2T_2^{-3}\right]$$

$$n_1 = \left[\frac{M_2}{M_1}\right]^1\left[\frac{L_2}{L_1}\right]^2\left[\frac{T_2}{T_1}\right]^{-3}$$

$$= \left[\frac{20}{1}\right]^1\left[\frac{10}{1}\right]^2\left[\frac{5}{1}\right]^{-3}$$

$$= \frac{20\times100}{5\times5\times5} = 16$$

$n_1 = 16$

Unit of power in new system = 16 Watt.

21. (*c*) $10^3(N) = M^1L^1T^{-2}$

$10^3 = [M]^1\,[10^3]^1\,[100]^{-2}$

$$M = \frac{10^3}{10^3\times(100)^{-2}} = 10000\text{ kg}$$

22. (*c*) In new system

Length $\rightarrow$ m 2m

Velocity $\rightarrow$ m/sec. 2m/sec

Force $\rightarrow$ kgm/sec^2 2kgm/sec^2

$\therefore$ Momentum (P) = mv = kg m/sec.

$$P = kg\frac{m}{sec}\times\frac{m}{m}\times\frac{sec}{sec}$$

$$P = kg\frac{m}{sec^2}\times\frac{m}{(m/sec)}$$

In new system

$$P^1 = \left(2kg\frac{m}{sec^2}\right)\times\frac{(2m)}{(2m/sec)}$$

$$P^1 = (2kg\,m/sec) = 2P$$

So, Here unit of momentum is doubled.

23. (*d*) Unit of Energy = $kg\,\frac{m^2}{sec^2}$

$$= \left(kg\,\frac{m}{sec^2}\right) \times (m)$$

Now unit of force and length are doubled.

$$= \left(2kg\,\frac{m}{sec^2}\right)(2m) = 4kg\,\frac{m^2}{sec^2}$$

So, Unit of Energy is 4 times.

24. (*c*) $K.E. = \frac{1}{2}mv^2$

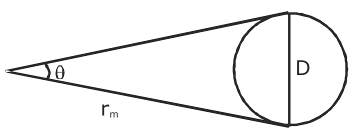
Dimension = $M^1L^2T^{-2}$

Now M.L are doubled

$= (2M)^1\,(2L)^2\,(T^{-2}) = 8\,M^1L^2T^{-2}$

So, K.E. will become 8 times.

25. (*b*) Take small angle approximation



$$\text{Sin}\,\theta = \frac{D}{r_m}$$

$$\text{Sin}\,0.50° = \frac{D}{r_m}$$

$$0.50 \times \frac{\pi}{180} = \frac{D}{384000}$$

$$D = 0.50 \times \frac{\pi}{180} \times 384000$$

$D = 3349.33 \Rightarrow D \approx 3350\,km.$

26. (*a*) $A = lb = 10.0 \times 1.00 = 10.00$

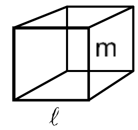
$$\frac{\Delta A}{A} = \frac{\Delta l}{l} + \frac{\Delta b}{b}$$

$$\frac{\Delta A}{10.00} = \frac{0.1}{10.0} + \frac{0.01}{1.00}$$

$$\Rightarrow \Delta A = 10.00\left(\frac{1}{100} + \frac{1}{100}\right)$$

$$= 10.00\left(\frac{2}{100}\right) = \pm 0.2\,cm^2.$$

27. (*b*)



$$\rho = \frac{m}{V} = \frac{m}{l^3}$$

Given : $\frac{\Delta m}{m} = \pm\ 2\% = \pm 2 \times 10^{-2}$ $\frac{\Delta l}{l}$

$= \pm 1\% = \pm 1 \times 10^{-2}$

$$\frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3\frac{\Delta l}{l}$$

$= 2 \times 10^{-2} + 3 \times 10^{-2}$

$= 5 \times 10^{-2} = 5\%$

28. (*a*) $g = 4\pi^2\frac{l}{T^2}$

$$\frac{\Delta l}{l} = 2\% = \pm 2 \times 10^{-2}$$

$$\frac{\Delta T}{T} = \pm 3\% = \pm 3 \times 10^{-2}$$

$$\Rightarrow \frac{\Delta g}{g} = \frac{\Delta l}{l} + \frac{2\Delta T}{T}$$

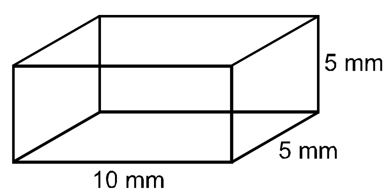
$= 2 \times 10^{-2} + 2 \times 3 \times 10^{-2} = 8 \times 10^{-2} = \pm 8\,\%$

29. (*b*) $\Delta t = 0.2$ s.

$t = 25$ s

$$T = \frac{t}{N} \Rightarrow \frac{\Delta T}{T} = \frac{\Delta t}{t} = \frac{0.2}{25} = 0.8\,\%$$

30. (*a*)



$v = lbh$

$$\frac{\Delta v}{v} = \frac{\Delta l}{l} + \frac{\Delta b}{b} + \frac{\Delta h}{h}$$

$$= \frac{0.1}{10} + \frac{0.1}{5} + \frac{0.1}{5} = \frac{0.5}{10} = \pm 5\%$$

31. (*d*) $\frac{\Delta x}{x} = 1\% = 10^{-2}$

$$\frac{\Delta y}{y} = 3\% = 3 \times 10^{-2}$$

$$\frac{\Delta z}{z} = 2\% = 2 \times 10^{-2}$$

$$t = \frac{xy^2}{z^3}$$

$$\frac{\Delta t}{t} = \frac{\Delta x}{x} + \frac{2\Delta y}{y} + \frac{3\Delta z}{z}$$

$= 10^{-2} + 2 \times 3 \times 10^{-2} + 3 \times 2 \times 10^{-2}$

$= 13 \times 10^{-2}$ $\therefore$ % error in t $= \frac{\Delta t}{t} \times 100 = 13\%$

32. (*c*) $D = (4.23 \pm 0.01)$ cm

$d = (3.89 \pm 0.01)$ cm

$\Delta t = (D - d)/2$

$$= \frac{(4.23 \pm 0.01) - (3.89 \pm 0.01)}{2}$$

$$= \frac{(4.23 - 3.89) \pm (0.01 + 0.01)}{2}$$

$= (0.34 \pm 0.02)/2$ cm

$= (0.17 \pm 0.01)$cm

33. (*b*) $m = 1.76$ kg

$M = 25\,m$

$= 25 \times 1.76$

$= 44.0$ kg

Note: Mass of one unit has three significant figures and it is just multiplied by a pure number (magnified). So result should also have three significant figures.

34. (*b*) $R_1 = (24 \pm 0.5)\,\Omega$

$R_2 = (8 \pm 0.3)\,\Omega$

$R_S = R_1 + R_2$

$= (32 \pm 0.8)\,\Omega$

35. (*b*) $\Delta l = 0.5$ mm

N = 100 divisions

zero correction = 2 divisions

Reading = Measured value + zero correction

$= (8 \times 0.5)\text{ mm} + (83 - 2) \times \frac{0.5}{100}$.

$= 4\text{ mm} + 81 \times \frac{0.5}{100}$ mm

$= 4.405$ mm

36. (*d*) $\Delta l = 1$ mm

N = 50 division

zero error = –6 Divisions

= – 0.12 mm

Diameter = Measured value + zero correction

$= 3 \times 1 + (6 + 31) \times \frac{1}{50}$

$= 3 + 0.74 = 3.74$ mm

37. (*a*) $D = 2 \times 1 + 5 \times \frac{10 - 9}{100} = 2.05$ cm

Advanced Level Multiconcept Questions

1. (*a*), (*b*), (*c*), (*d*)

All A,B & C are obvious.

(d) Derived quantity may have zero dimension in certain base quantity.
For example acceleration which is derived quantity, has zero dimensions in mass which is base quantity.

2. (*a*), (*c*), (*d*)

It is obvious

3. (*c*), (*d*)

By checking dimension in each option

Pressure $= \frac{F}{A} = \frac{[M^1L^1T^{-2}]}{[L^2]} = [M^1L^{-1}T^{-2}]$

Energy per unit volume $= \frac{\text{Energy}}{\text{Volume}}$

$= \frac{[M^1L^2T^{-2}]}{[L^3]} = [M^1L^{-1}T^{-2}]$

4. (*b*) $A = \frac{a}{t} = LT^{-3}$

5. (*a*) LT^{-4}

6. (*c*) $c = at = [LT^{-1}]$

7. (*c*) $F = \frac{[c]}{r^2} \Rightarrow [c] = Fr^2 = [MLT^{-2}]L^2$

8. (*d*) Kr = constant

$K = \frac{\text{constant}}{r} = \frac{1}{L} = L^{-1}$

9. (*b*) $F = \frac{C}{r^2} \Rightarrow C = Fr^2 = Nm^2$

10. (*a*) $\rightarrow$ (Q) $\rightarrow$ (*c*), (*b*) $\rightarrow$ (S) $\rightarrow$ (*a*), (*c*) $\rightarrow$ (P) $\rightarrow$ (*b*), (*d*) $\rightarrow$ (R) $\rightarrow$ (*d*)

$F = G\frac{m_1m_2}{r^2} \Rightarrow [G] = \frac{[F][r^2]}{[m_1m_2]} = \frac{MLT^{-2}L^2}{M^2} = M^{-1}L^3T^{-2}$

[Torque] = [f] [d] = $MLT^{-2}L = ML^2T^{-2}$

[Momentum] = [m] [v] = MLT^{-1}

$[p] = \frac{[F]}{[A]} = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$.

11. (i) $\rightarrow$ (Q) $\rightarrow$ (*d*), (ii) $\rightarrow$ (S) $\rightarrow$ (*b*), (iii) $\rightarrow$ (U) $\rightarrow$ (e), (iv) $\rightarrow$ (R) $\rightarrow$ (*a*), (v) $\rightarrow$ (T) $\rightarrow$ (f)
(vi) $\rightarrow$ (P) $\rightarrow$ (*c*)

(i) $U = \sigma A T^4 \Rightarrow [\sigma] = \dfrac{[U]}{[A][T^4]} = \dfrac{ML^2T^{-3}}{L^2K^4} = MT^{-3}K^{-4}$

(ii) $\lambda T = b \Rightarrow [b] = [\lambda][T] = LK$

(iii) $F = 6\pi\eta rv \Rightarrow [\eta] = \dfrac{[F]}{[r][v]} = \dfrac{MLT^{-2}}{L.\ LT^{-1}} = ML^{-1}T^{-1}$

(iv) $I = \dfrac{P}{A} = \dfrac{ML^2T^{-3}}{L^2} = ML^{o}T^{-3}$

(v) Energy $= \dfrac{1}{2}Mi^2 \Rightarrow [M] = \dfrac{[E]}{[i^2]} = ML^2T^{-2}A^{-2}$

(vi) $\dfrac{[U]}{[V]} = \dfrac{[B^2]}{[2\mu_0]}$

$= [\mu_0] = \dfrac{[B^2][V]}{[U]}$

Also, $F = qVB \Rightarrow B = \dfrac{F}{qv}$

$[\mu_0] = \dfrac{(F)^2[V]}{[q^2v^2][U]} = MLT^{-2}A^{-2}$

12. [1] **13.** [3] **14.** [4] **15.** [1] **16.** [0]

17. 2.6 cm^2 (in two significant figures)

18. [9%]

19. [92.1 cm]
Least count of slide calliper is 1 mm. Hence effective length of Pendulum = 90 + 2.1 = 92.1 cm

JEE Mains & Advanced Past Years Questions

JEE-MAIN PREVIOUS YEAR'S

1. (*a*) $\bar{x} = \dfrac{90+91+95+92}{4} = 92$

$\Delta x_1 = 90 - 92 = -2$

$\Delta x_2 = 91 - 92 = -1$

$\Delta x_3 = 95 - 92 = 3$

$\Delta x_4 = 92 - 92 = 0$

$|\Delta x| = \dfrac{2+1+3+0}{4} = 1.5$

2. (*b*) $LC = \dfrac{0.5}{50} = 0.01mm$

Zero error = –(50 – 45) × 0.01 *mm* = –0.05
Thickness = (0.5 + 25× 0.01) – (–0.05) = 0.80 *mm*

3. (*d*) $T = \dfrac{rhg}{2} \times 10^3$ N/m

$\dfrac{\Delta T}{T} = \dfrac{\Delta r}{r} + \dfrac{\Delta h}{h} + 0$

$100 \times \dfrac{\Delta T}{T} = \left(\dfrac{10^{-2} \times 0.01}{1.25 \times 10^{-2}} + \dfrac{10^{-2} \times 0.01}{1.45 \times 10^{-2}}\right)100$

$= (0.8 + 0.689)$

$= (1.489)$

$= 100 \times \dfrac{\Delta T}{T} = 1.489\%$

1.5%

4. (*b*) Density $= \dfrac{\text{Mass}}{\text{Volume}}$

$\dfrac{I\Delta d}{d} = \dfrac{1\Delta M}{M} + \dfrac{3\Delta L}{L}$

$= 1.5 + 3(a)$

$= 4.5\%$

5. (*d*) $\dfrac{F}{A} = y.\dfrac{\Delta l}{l}$; $[Y] = \dfrac{F}{A}$

Now from dimension

$F = \dfrac{ML}{T^2}$; $L = \dfrac{F}{M}.T^2$

$L^2 = \dfrac{F^2}{M^2}\left(\dfrac{V}{A}\right)^4$ $\cdot T = \dfrac{V}{A}$

$L^2 = \dfrac{F^2}{M^2A^2}\dfrac{v^4}{A^2}$ $\quad F = MA$

$L^2 = \dfrac{V^4}{A^2}$

$[Y] = \dfrac{[F]}{[A]} = F^1V^{-4}A^2$

6. (*a*) $\dfrac{128\text{kg}}{m^3} = \dfrac{125(50g)(20)}{(25m)^4(4)^3}$

$= \dfrac{128}{64}(20) = 40$

7. (*c*) $t = G^a h^b c^c$

$\Rightarrow M^\circ L^\circ T^1 = (M^{-1} L^3 R^{-2})^a (ML^2T^{-1})^b (LT^{-1})^c$

$\Rightarrow -a + b = \Rightarrow a = b$

$\Rightarrow 3a + 2b + c = 0$

$\Rightarrow c = -5a$

$\Rightarrow -2a - b - c = 1$

$\Rightarrow a = \frac{1}{2}; b = \frac{1}{2}; c = \frac{5}{2}$

8. (*b*) $\frac{L}{RCV} = \left[A^{-1}\right]$

9. (*b*) dimension of of $\sqrt{\frac{\varepsilon_0}{\mu_0}}$

$[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2][\mu_0] = [MLT^{-2}A^{-2}]$

dimensions of $\sqrt{\frac{\varepsilon_0}{\mu_0}} = \left[\frac{M^{-1}L^{-3}T^4A^2}{MLT^{-2}A^{-2}}\right]^{\frac{1}{2}}$

$= [M^{-2}L^{-4}T^6A^4]^{1/2} = [M^{-1}L^{-2}T^3A^2]$

10. (*c*) $X = 5\,YZ^2$

$Y = \frac{X}{5Z^2}$

$[Y] = \frac{[X]}{[Z^2]}$

$= \frac{A^2.M^{-1}L^{-2}.T^4}{(MA^{-1}T^{-2})^2}$

$= M^{-3}.L^{-2}.T^8.A^4$

11. (*b*) $p = k\,S^aI^bh^c$

where k is dimensionless constant

$MLT^{-1} = (MT^{-2})^a(ML^2)^b(ML^2T^{-1})^c$

$a + b + c = 1$

$2b + 2c = 1$

$-2a - c = -1$

$a = \frac{1}{2}$ $\quad b = \frac{1}{2}$ $\quad c = 0$

$S^{1/2}I^{1/2}h^0$

12. (*c*) $[\varepsilon_0] = M^{-1}L^{-3}\,T^4\,A^2$

$[\mu_0] = M\,L\,T^{-2}\,A^{-2}$

$[R] = M\,L^2\,T^{-3}\,A^{-2}$

$[R] = \left[\sqrt{\frac{\mu_0}{\varepsilon_0}}\right]$

13. (*c*) Zero error $= 0 + 3 \times \frac{0.5\text{mm}}{100} = 0.015$ mm

MSR $= 5.5 + 48 \times \frac{0.5}{100}$

$= 5.74$ mm.

$\therefore$ Thickness $= 5.74 - 0.015 = 5.725$ mm

14. (*c*) $v = \pi R^2h = \frac{\pi}{4}D^2h$

$= 4260\ \text{cm}^2$

$\frac{\Delta v}{v} = 2\frac{\Delta D}{D} + \frac{\Delta h}{h}$

$= \left(2 \times \frac{0.1}{12.6} + \frac{0.1}{34.2}\right)v$

$= \frac{2x426}{12.6} + \frac{426}{34.2}$

$= 67.61 + 12.459 = 80.075$

$\therefore$ $v = 4260 \pm 80\ \text{cm}^3$

15. (*b*) Least count $= \frac{\text{Pitch}}{\text{No. of divisions on circular scale}}$

$\Rightarrow 5 \times 10^{-6} = \frac{10^{-3}}{N}$ $\qquad \Rightarrow N = 200$

16. (*c*) Total Area $= A_1 + A_2 + \ldots\ldots\ldots. A_7$

$= A + A + \ldots\ldots.7$ times

$= 37.03\ m^2$

Addition of 7 terms all having 2 terms beyond decimal, so final answer must have 2 terms beyond decimal (as per rules of significant digits.)

17. **(Bonus)** $\rho = \frac{m}{v}$

maximum % error is S will be given by

$\frac{\Delta\rho}{\rho} \times 100\% = \left(\frac{\Delta m}{m}\right) \times 100\% + 3\left(\frac{\Delta L}{L}\right) \times 100\%$ ....(i)

which is only possible when error is small which is not the case in this question.

Yet if we apply equation (i), we get

$\Delta\rho = 3100\ \text{kg/m}^3$

Now, we will calculate error, without using approximation.

$\rho_{min} = \frac{m_{min}}{v_{max}} = \frac{9.9}{(0.11)^3} = 7438\ \text{kg}/m^3$

& $\rho_{max} = \frac{m_{max}}{v_{min}} = \frac{10.1}{(0.09)^3} = 13854.6\ \text{kg}/m^3$

$\Delta\rho = 67416.6\ \text{kg/m}^3$

No option is matching.

Therefore this question should be awarded bonus

18. (*b*) Energy density in magnetic field = $\dfrac{B^2}{2\mu_0}$

$$= \frac{\text{Force} \times \text{displacement}}{(\text{displacement})^3} = \frac{MLT^{-2}L}{L^3} = ML^{-1}T^{-2}$$

19. (*b*) $[ML^2T^{-2}]$

$[hc] = [ML^3T^{-2}]$

$[c] = [LT^{-1}]$

$[G] = [M^{-1}L^3T^{-2}]$

20. (*c*) Energy = Force × Distance

$\Rightarrow$ [Energy] = $\dfrac{P}{T} \times \sqrt{A}$

$$= \left[PA^{\frac{1}{2}}T^{-1}\right]$$

21. (*a*) · [Young's modulus] = $\left[\dfrac{\text{Force}}{\text{Area}}\right]$

$\Rightarrow$ [Young's modulus] = FA^{-1}

$\Rightarrow$ [Young's modulus] = $FA^{-1}V^0$

22. (*d*) Solar constant = $\dfrac{E}{AT}$

$$\frac{M^1L^2T^{-2}}{L^2T} = M^1T^{-3}$$

23. (*c*) $= \dfrac{IFv^2}{WL^4}$

$$\therefore\ [x] = \frac{(ML^2)\times(MLT^{-2})\times(LT^{-1})^2}{(ML^2T^{-2})\times L^4}$$

$= ML^{-1}T^{-2}$

= [Energy density]

24. (*b*) $\dfrac{dQ}{dt} = \dfrac{KA(\Delta T)}{x}$

$$\Rightarrow [K] = \frac{ML^2T^{-2}\times L}{T\times L^2\times K}$$

$= MLT^{-3}K^{-1}$

25. (*c*) $C = \dfrac{1}{\sqrt{\mu_0\varepsilon_0}} = X$

$$C = \frac{E}{B} = Y$$

$\tau = RC = t$

$\Rightarrow [X] = [Y] = [Z]$

26. (*d*) (official)

(a) (Reso)

$$\frac{\Delta T}{T} = \frac{1}{2}\left(\frac{\Delta g}{g} + \frac{\Delta L}{L}\right)$$

$$\frac{\Delta g}{g} = \frac{2\Delta T}{T} + \frac{\Delta L}{L};\quad = 2\left(\frac{1}{50}\right) + \frac{0.1}{25.0}$$

$= 4.4\,\%$

27. (*d*) Pitch = $\dfrac{3}{6} = 0.5\text{mm}$

$$\text{L.C.} = \frac{0.5\text{mm}}{50} = \frac{1}{500}\text{mm} = 0.01\text{mm}$$

$= 0.001$ cm

28. (*b*) $\rho = \dfrac{M}{V} \Rightarrow \left|\dfrac{\Delta\rho}{\rho}\times 100\right| = \left|\dfrac{\Delta V}{V}\times 100\right|$

$$\left|\frac{\Delta\rho}{\rho}\times 100\right| = 3\alpha\Delta T \times 100 \text{.....(i)}$$

Given $\dfrac{\Delta l}{l} = 2\times 10^{-4} \Rightarrow \alpha\Delta T = 2\times 10^{-4}$

$\Rightarrow \alpha = 2 \times 10^{-5}$

From (i), $\dfrac{\Delta\rho}{\rho}\times 100 = 6\times 10^{-5}\times 10\times 100 = 0.06$

29. (*c*) Least count of V.C = $\left|\left(1 - \dfrac{9}{10}\right)\right| \times 1\text{mm}$

$= 0.1$ mm

$\therefore$ Zero error = $7 \times 0.1 = 0.7$ mm

positive error

Measured value = $(31 + 4 \times 0.1)$ mm

= 31.4 mm

$\therefore$ Length of cylinder = $31.4 - 0.7$

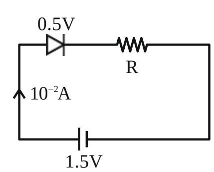
= 30.7 mm

= 3.07 cm

30. (*a*) Least count = $\dfrac{0.1}{50}$ cm = 0.002 cm

Thickness of object = Main scale Reading + Circular scale reading × least count

31. (*d*)



$$R = \frac{V}{I}$$

$$\frac{1}{10^{-2}} = 100\Omega$$

32. (*b*) $\dfrac{\Delta z}{z} = 2\dfrac{\Delta A}{A} + \dfrac{2}{3}\dfrac{\Delta b}{b} + \dfrac{1}{2}\dfrac{\Delta c}{c} + 3\dfrac{\Delta d}{d}$

$$= 2\times 2 + \frac{2}{3}\times 1.5 + \frac{1}{2}\times 4 + 3\times 2.5 = 14.5\%$$

33. (*b*) $d_{av} = 5.5375\,mm$

$\Delta d = 0.07395\,mm$

∵ Measured data are up to two digits after decimal

$\therefore\ d = (5.54 \pm 0.07)\,mm$

34. [1050.00]

$$\rho = \frac{m}{\frac{4}{3}\pi\left(\frac{d}{2}\right)^3} \quad \therefore\ \%\ \frac{\Delta\rho}{\rho} = \frac{\Delta m}{m} + 3\left(\frac{\Delta d}{d}\right)$$

$$= 6 + 3\times 1.5 = 10.5\% = \left(\frac{1050}{100}\right)\%$$

35. (*b*) Reading $=$ MSR $+$ VSD $\times$ LC $-$ zero error

$$\text{Reading} = 8.5 + \frac{(0.1)\times 6}{10} - \frac{0.2}{10} = 8.54\,cm$$

36. (*c*) $$\frac{\Delta Y}{Y} = \left(\frac{\Delta m}{m}\right) + \left(\frac{\Delta g}{g}\right) + \left(\frac{\Delta A}{A}\right) + \left(\frac{\Delta l}{l}\right) + \left(\frac{\Delta L}{L}\right)$$

$$= \left(\frac{1g}{1kg}\right) + 0 + 2\left(\frac{\Delta r}{r}\right) + \left(\frac{\Delta l}{l}\right) + \left(\frac{\Delta L}{L}\right)$$

$$= \left(\frac{1g}{1kg}\right) + 2\left(\frac{0.001cm}{0.2\,cm}\right) + \left(\frac{0.001cm}{0.5cm}\right) + \left(\frac{0.001m}{1m}\right)$$

$$= \left(\frac{1}{1000}\right) + 2\left(\frac{1\times 10}{2\times 10^3}\right) + \left(\frac{1}{5}\times\frac{10^2}{10^3}\right) + \left(\frac{1}{10^3}\right)$$

$$= \frac{1}{1000} + \frac{1}{100} + \frac{2}{10^3} + \frac{1}{10^3}$$

$$= \frac{1+10+2+1}{1000} = \frac{14}{1000}\times 100\%$$

$= 1.4\%$.

37. (*a*) VSD $= (n-1)$ MSD

$\Rightarrow$ VSD $= \left(\frac{R-1}{R}\right)$ MSD

$\Rightarrow$ L.C. $= 1$ MSD $- 1$ VSD

$= 1$ MSD $- \left(\frac{R-1}{R}\right)$ MSD

$= 1$ MSD $- 1$ MSD $+ \frac{MSSD}{R} = \frac{MSQD}{R} = \frac{a}{R}$ cm

$= \frac{10R}{R}$ mm

JEE-ADVANCED PREVIOUS YEAR'S

1. (*a*) $d = \Delta l = \frac{0.5}{100}$ mm

$$y = \frac{4MLg}{\pi l d^2}$$

$$\left(\frac{\Delta y}{y}\right)_{max} = \frac{\Delta l}{l} + 2\frac{\Delta d}{d}$$

error due to l measurement $\frac{\Delta l}{l} = \frac{0.5/100\,mm}{0.25\,mm}$

error due to d measurement

$$2\frac{\Delta d}{d} = \frac{2\times\frac{0.5}{100}}{0.5\,mm} = \frac{0.5/100}{0.25}$$

So error in y due to l measurement = error in y due to d measurement

2. (*c*) (p) $U = \frac{1}{2}kT \Rightarrow ML^2T^{-2} = [k]\,K \Rightarrow [K] = ML^2T^{-2}K^{-1}$

(q) $F = \eta A\frac{dv}{dx} \Rightarrow [\eta] = \frac{MLT^{-2}}{L^2LT^{-1}L^{-1}} = ML^{-1}T^{-1}$

(r) $E = h\nu \Rightarrow ML^2T^{2} = [h]\,T^{-1} \Rightarrow [h] = ML^2\,T^{-1}$

(s) $\frac{dQ}{dt} = \frac{kA\Delta\theta}{l} \Rightarrow [k] = \frac{ML^2T^{-3}L}{L^2K} = MLT^{-3}K^{-1}$

3. (*b*) $50\,VSD = 2.45\,cm$

$1\,VSD = \frac{2.45}{50}\,cm = 0.049\,cm$

Least count of vernier = 1MSD – 1 VSD

$= 0.05\,cm - 0.049\,cm$

$= 0.001\,cm$

Thickness of the object = Main scale reading + vernier scale reading × least count

$= 5.10 + (24)(0.001)$

$= 5.124\,cm.$

4. (*a, b, d*) $T = 2\pi\sqrt{\frac{7}{5}\frac{(R-r)}{g}}$

$$\ln T = \ln 2\pi\sqrt{\frac{7}{5}} + \frac{1}{2}\ln(R-r) + \frac{1}{2}\ln g$$

$$\frac{\Delta g}{g} = 2\frac{\Delta T}{T} + \frac{\Delta R + \Delta r}{R-r}$$

$$\frac{\Delta g}{g}\times 100 = \left(2\times\frac{0.02}{0.556} + \frac{1+1}{60-10}\right)\times 100$$

$= 11.2\%$ 11%

$$\frac{\Delta r}{r}\times 100 = \frac{1}{10}\times 100 = 10\%$$

$$\frac{\Delta T}{T}\times 100 = \frac{0.02}{0.556}\times 100 = 3.57\%$$

Hence, (a, b, d)

5. (*d*) $2d\sin\theta = \lambda$

$$d = \frac{\lambda}{2\sin\theta}$$

differntiate

$$\partial(d) = \frac{\lambda}{2}\,\partial(\text{cosec}\theta)$$

$$\partial(d) = \frac{\lambda}{2}(-\operatorname{cosec}\theta\cot\theta)\partial\theta$$

$$\partial(d) = \frac{-\lambda\cos\theta}{2\sin^2\theta}\partial\theta$$

as θ = increases , $\frac{\lambda\cos\theta}{2\sin^2\theta}$ decreases

2nd Method

$$d = \frac{\lambda}{2\sin\theta}$$

$\ell n\, d = \ell n\, \lambda - \ell n\, 2 - \ell n\, \sin\theta$

$$\frac{\Delta(d)}{d} = 0 - 0 - \frac{1}{\sin\theta}\times\cos\theta(\Delta\theta)$$

Fractional error $|+(d)| = |\cot\theta\, \Delta\theta|$

Absoulute error $\Delta d = (d\cot\theta)\,\Delta\theta$

$$\frac{d}{2\sin\theta}\times\frac{\cos\theta}{\sin\theta}$$

$$\Delta d = \frac{\cos\theta}{\sin^2\theta}$$

6. [3]

$d = k\,(\rho)^a\,(S)^b\,(f)^c$

$$\left[\frac{M}{L^3}\right]^a \left[\frac{M^1L^2T^{-2}}{L^2T}\right]^b \left[\frac{1}{T}\right]^c$$

$0 = a + b$

$1 = -3a \Rightarrow a = -\frac{1}{3}$

So $\quad b = \frac{1}{3}$

So $n = 3$

7. (*b*,*d*)

$$[k_BT] = [Fl]$$

$$\&\left[\frac{q^2}{\in}\right] = [Fl^2]$$

8. (*d*) $R_1 = 2.8 + 0.01\times 7 = 2.87$

$R_2 = 2.8 + (8\text{MSD} - 7\text{VSD}) = 2.8 + (8\times 0.1 - 7\times\frac{11}{10})$

$= 2.83$

Hence, (*d*)

9. (*c*) We have $\frac{E}{C} = B$

$\therefore\quad [B] = \frac{[E]}{[C]} = [E]L^{-1}T^1$

$\Rightarrow\quad [E] = [B]\,[L]\,[T]^{-1}$

10. (*d*) We have

$$C = \frac{1}{\sqrt{\mu_0 \in_0}}$$

$\therefore\quad [C^2] = \left[\frac{1}{\mu_0\in_0}\right]$

$\Rightarrow\quad L^2T^{-2} = \frac{1}{[\mu_0][\in_0]}$

$\Rightarrow\quad [\mu_0] = [\mu_0] = [\in_0]^{-1}[L]^{-2}[T]^2$

11. (*a*,*b*,*d*)

Mass $= M^0L^0T^0$

$MVr = M^0L^0T^0$

$M^0\frac{L^1}{T^1}\,.\,L^1 = M^0L^0T^0$

$L^2 = T^1$ ....(*a*)

Force $= M^1L^1T^{-2}$ (in SI)

$= M^0L^1L^{-4}$ (In new system from equation (*a*))

$= L^{-3}$

Energy $= M^1L^2T^{-2}$ (In SI)

$= M^0L^2L^{-4}$(In new system from equation (*a*))

$= L^{-2}$

Power $= \frac{\text{Energy}}{\text{Time}}$

$= M^1L^2T^{-3}$ (in SI)

$= M^0L^2L^{-6}$(In new system from equation (*a*))

$= L^{-4}$

Linear momentum $= M^1L^1T^{-1}$ (in SI)

$= M^0L^1L^{-2}$(In new system from equation(*a*))

$= L^{-1}$

12. (c) Given $10\text{VSD} = 9\text{MSD}$

$1\text{VSD} = \frac{9}{10}\text{MSD}$ Least count

$= 1\text{MSD} - 1\text{VSD} = \left(1 - \frac{9}{10}\right)\text{MSD}$

$= 0.1\text{MSD} = 0.1\times 0.1\text{cm} = 0.01\text{cm}$

As '0' of V.S. lie before ' 0 ' of M.S.

Zero error $= -[10-6]$ L.C.

$= -4\times 0.01\text{cm}$

$= -0.04\text{cm}$

Reading $= 3.1\text{cm} + 1\times\text{LC} = 3.4\text{cm} + 1\times 0.01\text{cm} = 3.11\text{cm}$

True diameter = Reading - Zero error

$= 3.11 - (-0.04)\text{cm} = 3.15\text{cm}$

13. (*b*, *d*)

$$\vec{S} = [\vec{E}\times\vec{B}]\frac{1}{\mu_0}$$

S is pointing vector denotes flow of energy per unit area per unit time

$$\vec{S} = \frac{\text{watt}}{\text{m}^2}$$

Hence *b*, *d* are correct