2 UNITS AND MEASUREMENTS

PHYSICAL QUANTITIES

Those quantities which can describe the laws of physics and possible to measure are called physical quantities.
A physical quantity is that which can be measured.
Physical quantity is completely specified;
If it has

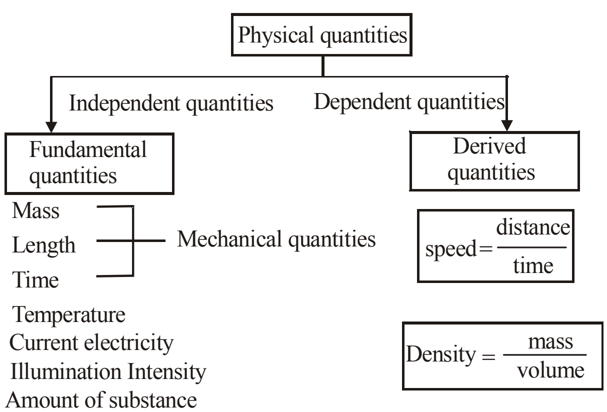
- Only Numerical value (ratio) Ex, Refractive index, dielectric constant etc.
- Only magnitude (scalar), Ex. Mass, charge, etc.
- Magnitude and direction (Vector) Ex. Displacement, Torque, etc.

Note :

(i) There are also some physical quantities which are not completely specified even by magnitude, unit and direction. These physical quantities are called tensors. eg. moment of Inertia.

(ii) Physical quantity = Numerical value × unit

TYPES OF PHYSICAL QUANTITIES



The physical quantities which do not depend upon other quantities are called fundamental quantities.
In M.K.S. system the fundamental quantities are mass, length and time.
In standard International (S.I.) system the Fundamental quantities are mass, length, time, temperature, illuminating power (or luminous intensity), current and amount of substance.

UNITS

The unit of a physical quantity is the reference standard used to measure it.
For the measurement of a physical quantity a definite magnitude of quantity is taken as standard and the name given to this standard is called unit.

PROPERTIES OF UNIT

(a) The unit should be well-defined.
(b) The unit should be of some suitable size.
(c) The unit should be easily reproducible.
(d) The unit should not change with time.
(e) The unit should not change with physical condition like pressure, temperature etc.
(f) Unit should be of proper size.

TYPES OF UNITS

(i) Fundamental unit
(ii) Derived unit
(iii) Practical unit

FUNDAMENTAL UNITS

The units defined for the fundamental quantities are called fundamental units.

1. Unit of mass = Kilogram
(1 kilogram is defined as the mass of a platinum – iridium cylinder kept in National Bureau of weights and measurements, Paris)

2. Unit of length = Meter
(Travelled distance by light in vacuum in 1/299,792,458 second or It is equal to 1650763.73 wave length emitting from Kr^{86})

3. Unit of Time = Sec.
(The time interval in which Cesium-133 atom vibrates 9,192,631, 770 times)

4. Unit of Temperature = Kelvin
(It is defined as the (1/273.16) fraction of thermo dynamic temperature of triple point of water.)
Triple Point of Water is the temperature at which ice, water and water vapours co-exist.

5. Unit of current = Ampere
(Amount of current which produces a force of 2×10^{-7} N on per unit length acts between two parallel wires of infinite length and negligible cross-section area placed at 1 m distance in vacuum)

6. Unit of luminous Intensity = Candela
(Amount of intensity on 1/60000 m^2 area of blackbody in the direction perpendicular to its surface at freezing point of platinum 2042K at pressure of 101325 N/m^2.)

7. Unit of quantity of Substance = mole
(It is the amount of a substance which has same number of elementary entities as in 12 gm of Carbon)

BASIC UNIT SYSTEMS

Quantity	Name of system		
	C.G.S.	F.P.S.	M.K.S.
Length	centimeter	foot	meter
Mass	gram	pounds	kilogram
Time	second	second	second

S.I. UNITS

Length meter(m)
Mass kilogram (kg)
Time second (s)
Temperature kelvin(K)
Electric Current ampere(A)
Luminous Intensity candela (Cd)
Amount. of Substance mole (mol)

In S.I. units there are two supplementary units.
Radian (rad) : Unit of plane angle.
Steradian (st) : Unit of solid angle.

S.I. PREFIXES

S.No.	Perfix	Symbol	Power of 10
1	exa	E	18
2	peta	P	15
3	tera	T	12
4.	giga	G	9
5.	mega	M	6
6.	kilo	K	3
7.	hecto	h	2
8.	deca	da	1
9.	deci	d	–1
10.	centi	c	–2
11.	milli	m	–3
12.	micro	μ	–6
13.	nano	n	–9
14	pico	p	–12
15.	femto	f	–15
16.	atto	a	–18

PRACTICAL UNITS OF LENGTH

1. Light year = 9.46×10^{15} m
2. Parsec = 3.084×10^{16} m
3. Fermi = 10^{-15} m
4. Angstrom (A°) = 10^{-10} m
5. Micron/Micrometer = 10^{-6} m
6. Nano meter = 10^{-9} m
7. Picometer = 10^{-12} m
8. Acto meter = 10^{-18} m
9. Astro nomical unit (A.U.) = 1.496×10^{11} m

DERIVED UNITS

1. Unit of Speed

$$(\text{Speed/velocity}) = \frac{\text{distance (displacement)}}{\text{time}}$$

$$\Rightarrow (\text{Unit of Speed/velocity}) = \frac{\text{meter}}{\text{sec}}.$$

2. Unit of Acceleration

By formula; $a = \frac{v}{t} \Rightarrow$ Unit of 'a' $= \frac{m/s}{s} = m/s^2$

3. Unit of Force

$F = ma \quad \Rightarrow$ Unit of force = kg × m/s^2 = Newton

DIMENSIONS OF PHYSICAL QUANTITIES

The limit of a derived quantity in terms of necessary basic units is called dimensional formula and the raised powers on the basic units are dimensions.

The basic units are represented as :

Kilogram= M Meter = L
Second = T Ampere = A
Kelvin = K or θ Candela = Cd
Mole = mol.

Note :

1. A physical quantity may have a number of units but their dimensions would be same,
   Ex. The units of velocity are: cms^{-1}, ms^{-1}, km s^{-1}. But the dimensional formula is $M^0L^1T^{-1}$.
2. Dimension does not depend on the unit of quantity.

DIMENSIONAL EQUATION

When a dimensional formula is equated to its physical quantity then the equation is called Dimensional Equation.

Ex. Dimensional equation of Force :
By F = ma
$\Rightarrow$ Dimension Equation of
$F = [M^1][L^1 T^{-2}] = [MLT^{-2}]$

Ex. Dimensional equation of Energy :
By E = W = Force × Displacement
Dimensional equation of
$E = [M^1 L^1 T^{-2}][L^1] = [M^1 L^2 T^{-2}]$

NOTE

1. Pure number and pure ratio are dimension less.
   Ex. 1, 2, π, e^x, logx, $\sin\theta$, $\cos\theta$ etc. and refractive index.
2. Dimension less quantity may have unit.
   Ex. Angle and solid angle.
3. The method of dimensions can not be applied to derive the formula if a physical quantity depends on more than three physical quantities.

TO FIND DIMENSIONAL FORMULA

Procedure :

(i) Firstly we write the formula.
(ii) Now change derived units in the fundamental units.
(iii) At last solve the equation except given quantity.

DIMENSIONS IN MECHANICS

Quantities	Dimensional eqn.	Quantities	Dimensional eqn.
Distance Displacement, length/depth/thickness wave length	$M^0L^1T^0$	Force, Weight Tension centripetal force	$M^1L^1T^{-2}$
Mass, Inertia, Intertial mass, Gravitational mass	$M^1L^0T^0$	Work Energy Torque Moment of couple Heat	$M^1L^2T^{-2}$
Speed, velocity, velocity of sound velocity of light	$M^0L^1T^{-1}$	Linear Momentum Impulse	$M^1L^1T^{-1}$
Acc.(a) Acc. due to gravity(g)	$M^0L^1T^{-2}$	Surface Tension	$M^1L^0T^{-2}$
Angular velocity, Velocity gradient, Decay constant of (λ) linear frequency Activeness	$M^0L^0T^{-1}$	Pressure, Coefficient of Elasticity Young Modulus Bulk Modulus Stress	$M^1L^{-1}T^{-2}$
Wave Number Propagation constant (K), Rydberg constant	$M^0L^{-1}T^0$	Plank Constant, Angular momentum	$M^1L^2T^{-1}$
Gravitational constant	$M^{-1}L^3T^{-2}$	Viscous coefficient	$M^1L^{-1}T^{-1}$

DIMENSIONS IN HEAT

Quantities	Dimensional eqn.
Temperature	$M^0\ L^0\ T^0\ \theta^1$
Latent heat	$M^0\ L^2\ T^{-2}\ \theta^0$
Specific heat	$M^0\ L^2\ T^{-2}\ \theta^{-1}$
Coefficient of thermal expansion	$M^0\ L^0\ T^0\ \theta^{-1}$
Coeff. of thermal conductivity	$M^1\ L^1\ T^{-3}\ \theta^{-1}$
Mechanical equivalent (J)	$M^0\ L^0\ T^0$
Stephan constant	$M^1\ L^0\ T^{-3}\ k^{-4}$
Wien's constant	$M^0\ L^1\ T^0\ \theta^1$
Boltz mann constant	$M^1\ L^2\ T^{-2}\ \theta^{-1}$

DIMENSION OF MAGNETIC QUANTITIES

Quantities	Dimensional eqn.
Magnetic induction	$M^1L^0T^{-2}A^{-1}$
Permeability of magnet (μ)	$M^1L^1T^{-2}A^{-2}$
Self inductance or Mutual inductance	$M^1L^2T^{-2}A^{-2}$
Bohr magnaton (μ_B)	$M^0L^2T^0A^1$

DIMENSIONS IN ELECTRICITY

Quantities	Dimensional eqn.	Quantities	Dimensional eqn.
Charge	$A^1\ T^1$	Electric permittivity of free space	$M^{-1}\ L^{-3}\ T^4\ A^2$
Current	A^1	Resistance Reactance Impedance	$M^1\ L^2\ T^{-3}\ A^{-2}$
Potential gradient Electric field Intensity of Electric field	$M^1\ L^1\ T^{-3}\ A^{-1}$	Electrical conductance Admittance Suseptance	$M^{-1}\ L^{-2}\ T^3\ A^2$
Potential difference Potential Potential energy Electromotive force	$M^1\ L^2\ T^{-3}\ A^{-1}$	Electrical flux	$M^1L^3T^{-3}A^{-1}$
Electrical capacitance	$M^{-1}\ L^{-2}\ T^4\ A^2$	Specific Resistance	$M^1\ L^3\ T^{-3}\ A^{-2}$

THE PRINCIPLE OF HOMOGENEITY OF DIMENSION

The dimension of physical quantity on the left hand side of dimensional equation should equal to the net dimensions of all physical quantities on the right hand side of it.

Example 1 :

If in the form $x = 3yz^2$, x and z represent electrical capacitances and magnetic induction then calculate dimensional equation of y.

Sol. By the principal of homogeneity of dimension

Dimension equation of x = Dimension equation of $(3yz^2)$

$M^{-1}L^{-2}T^4A^2$ = Dimension equation of (y) $\times (M^1L^0T^{-2}A^{-1})^2$

Dimension of (y) = $M^{-3}L^{-2}T^8A^4$

USES OF DIMENSIONAL EQUATIONS

1. Conversion of one system of units in to another
2. Checking the accuracy of various formula or equation
3. Derivation of Formula.

CONVERSION OF ONE SYSTEM OF UNITS INTO ANOTHER

Let the numerical values are n_1 and n_2 of a given quantity Q in two unit system and the units are–

$U_1 = M_1^a L_1^b T_1^c$ and $U_2 = M_2^a L_2^b T_2^c$

(in two systems respectively)

Therefore, By the principle nu = constant

$\Rightarrow n_2u_2 = n_1u_1$

$n_2[M_2^a L_2^b T_2^c] = n_1[M_1^a L_1^b T_1^c]$

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

Example 2 :

How many dynes are in 20 N ?

Sol. Dimensional formula of force (F) = $M^1L^1T^{-2}$

$n_1 = 20, n_2 = ?$

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

$$n_2 = 20\left[\frac{1\,kg}{gm}\right]^1 \left[\frac{1\,m}{cm}\right]^1 \left[\frac{1\,sec.}{sec}\right]^{-2} = 20\left[\frac{10^3\,gm}{gm}\right]^1 \left[\frac{10^2\,cm}{cm}\right]^1$$

$n_2 = 20 \times 10^5$

$20\,N = 20 \times 10^5$ dyne

PRINCIPLE OF HOMOGENEITY

The dimensions of both sides in an equation are same.

Ex. $s = ut + \frac{1}{2}gt^2$

$[L] = [LT^{-1}.T] + [LT^{-2}.T^2]$; $[L] = [L] + [L]$

DEFECTS OF DIMENSIONAL ANALYSIS

(i) While deriving a formula the proportionality constant cannot be found.

(ii) The formula for a physical quantity depending on more than three other physical quantities cannot be derived. It can be checked only.

(iii) The equations of the type $v = u \pm at$ cannot be derived. They can be checked only.

(iv) The equations containing trigonometrical functions ($\sin\theta$, $\cos\theta$, etc), logarithmic functions ($\log x$, $\log x^3$ etc) and exponential functions (e^x, e^{x^2} etc) cannot be derived. They can be checked only.

TO CHECK THE ACCURACY OF A FORMULA

It is based on homogeneity principle of dimension according to it formula is correct when L.H.S. = R.H.S. Dimensionally.

Example 3 :

Test the correctness of the formula $T = 2\pi\sqrt{\frac{\ell}{g}}$, where,

T = time period, ℓ = length of pendulum and g = Acc. due to gravity.

Sol. L.H.S. Dimension Equation of T $\Rightarrow M^0L^0T^1$

R.H.S. Dimension equation of;

$$2\pi\sqrt{\frac{\ell}{g}} \Rightarrow \left[\frac{M^0L^1T^0}{L^1T^{-2}}\right]^{1/2} = [M^0L^0T^2]^{1/2} = M^0L^0T^1$$

$\because$ L.H.S. = R.H.S.;

Dimensionally. Therefore, the given formula is correct.

TO DERIVE THE FORMULA BY DIMENSIONAL ANALYSIS

Let a physical quantity x depends on the another quantities P, Q and R. Then $x \propto (P)^a (Q)^b (R)^c$

$x = k(P)^a (Q)^b (R)^c$ .....(1)

Consider dimensional formula of each quantity in both side

$M^xL^yT^z = [M^{x_1} L^{y_1} T^{z_1}]^a [M^{x_2} L^{y_2} T^{z_2}]^b [M^{x_3} L^{y_3} T^{z_3}]^c$

$\Rightarrow M^xL^yT^z = M^{ax_1} L^{ay_1} T^{az_1} M^{bx_2} L^{by_2} T^{bz_2} M^{cx_3} L^{cy_3} T^{cz_3}$

$\Rightarrow M^xL^yT^z = M^{ax_1+bx_2+cx_3} L^{ay_1+by_2+cy_3} T^{az_1+bz_2+cz_3}$

Now comparing the powers of both side –

$ax_1 + bx_2 + cx_3 = x$ ....(2)

$ay_1 + by_2 + cy_3 = y$ ....(3)

$az_1 + bz_2 + cz_3 = z$ ....(4)

After solving equation (2), (3) and (4) value of a, b and c will be m, n and o may be find out

Now substitute the values of x, y and z in equation (1)

Then obtained formula will be : $x = (P)^m (Q)^n (R)^o$

Example 4 :

The time of oscillation (T) depends upon the density 'd' radius 'r' and surface Tension (s). Obtain the formula for T by dimensional method.

Sol. $T \propto (d)^a (r)^b (s)^c$

$\Rightarrow T = k(d)^a (r)^b (s)^c$ ....(1)

Taking dimension of each quantity in both sides.

$M^0L^0T^1 = [M^1L^{-3}T^0]^a\,[L^1]^b\,[M^1L^0T^{-2}]^c$

$\Rightarrow\ M^0L^0T^1 = [M^{a+c}][L^{-3a+b}]\,[T^{-2c}]$

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

Comparing the dimensions of both sides.

$a + c = 0$ ....(2) $\quad -3a + b = 0$ ....(3)

$-2c = 1$ or $c = -1/2$ ....(4)

Substituting value of c in equation (3)

$a + (-1/2) = 0 \quad \Rightarrow a = 1/2$

Now putting a = 1/2 in equation (3)

$-3\left(\frac{1}{2}\right) + b = 0 \quad \Rightarrow b = 3/2$

on substituting value a, b and c in equation (1)

$$T = k\,(d)^{1/2}\,(r)^{3/2}\,(s)^{-1/2} \quad \Rightarrow T = \sqrt{\frac{r^3 d}{s}}$$

TRY IT YOURSELF-1

Q.1 How many of the following statements do you consider to be true:

(1) Mathematics is the language of physics and can be a source of factual knowledge.

(2) The laws of physics are exact, definitive, and absolute.

(3) The body of knowledge in physics is a collection of many directly perceived facts.

(4) Aptitude is as (if not more) important than personal effort in learning physics.

(5) The methods of science are situation specific.

(a) 1 (b) 2 (c) 3
(d) 4 (e) 5 (f) 0

Q.2 Which of the following statements constitutes a scientific hypothesis?

(1) Atoms are the smallest particles of matter that exist.

(2) Space is permeated with a substance that is undetectable.

Q.3 What are the SI units of power?

(A) m/s^2 (B) $kg\text{-}m/s^2$
(C) $kg\text{-}m^2/s^2$ (D) $kg\text{-}m^2/s^3$

Q.4 What are the dimensions of energy?

(A) $[L]\,[T^{-2}]$ (B) $[M]\,[L]\,[T^{-2}]$
(C) $[M]\,[L^2]\,[T^{-2}]$ (D) $[M]\,[L^2]\,[T^{-3}]$

Q.5 Using m, ℓ and t as the symbols for the dimension of mass, length and time, what are the dimensions of force and momentum?

Q.6 A mass M is suspended from a string of length L in a gravitational field $\vec{g}$. The mass swings back and forth on a plane at the end of the fixed-length string. Use dimensional analysis to determine how the period of oscillation depends on M, L and g.

Q.7 If the potential energy U of a body depends on its mass m, height h from ground and acceleration due to gravity g, then find expression for potental energy U.

Q.8 If velocity v, acceleration a and density ρ are taken as fundamental quantities, then find the dimensional formula for kinetic energy K.

Q.9 In relation $N = \frac{\alpha}{\beta} e^{-\alpha E/t}$, N is the number of nuclei, E is energy and t is time. Find dimension of α and β.

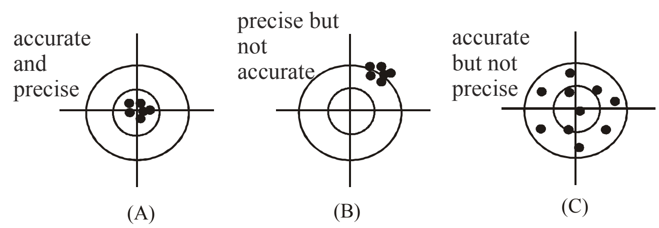
Q.10 The position (x) of a particle depends on a velocity (v) and time (t) as given by relation $x = Av + \frac{B}{A+t}$. Find dimension of AB.

ANSWERS

(1) (f) **(2)** (1) **(3)** (D)
(4) (C) **(5)** $[F] = m\,\ell\,t^{-2}$; $[p] = m\,\ell\,t^{-1}$
(6) $T \propto \sqrt{\frac{\ell}{g}}$ **(7)** mgh **(8)** $[v^8a^{-3}\rho^1]$
(9) $[M^{-1}L^{-2}T^3]$ **(10)** $[LT^2]$

ACCURACY, PRECISION OF INSTRUMENTS AND ERRORS IN MEASUREMENT

Accuracy and Precision are two terms that have very different meanings in experimental physics. We need to be able to distinguish between an accurate measurement and a precise measurement. An accurate measurement is one in which the results of the experiment are in agreement with the ‘accepted’ value.



Note this only applies to experiments where this is the goal measuring the speed of light, for example. A precise measurement is one that we can make to a large number of decimal places. The following diagrams illustrate the meaning of these terms:

A- Precise ad accurate, B- Precise but not accurate, C- Accurate but imprecise.

When successive measurements of the same quantity are repeated there is a distribution of values obtained. In experimental physics it is vital to be able to measure and quantify this uncertainty. (The words "error" and "uncertainty" are often used interchangeably by physicists - this is not ideal - but get used to it!)

Types of Error :

We need to identify the following types of errors:

Systematic errors - these influence the accuracy of a result.

Random errors - these influence precision.

Systematic errors : Systematic errors are a constant bias that are introduced into all your results. Unlike Random Errors, which can be reduced by repeated measurements, systematic errors are much more difficult to combat and cannot be detected by statistical means.

They cause the measured quantity to be shifted away from the 'true' value.

When you design an experiment, you should design it in a way so as to minimise systematic errors. For example, when measuring electric fields you might surround the experiment with a conductor to keep out unwanted fields. You should also calibrate your instruments, that is use them to measure a known quantity. This will help tell you the magnitude of any remaining systematic errors.

Some sources of systematic errors are :

(a) **Instrumental errors :** Due to imperfect design or calibration of the measuring instrument.

(b) Imperfection in experimental technique or procedure

(c) **Personal errors :** They arise due to an individual's bias, lack of proper setting of the apparatus or individual's carelessness in taking observations without taking proper precautions, etc.

(d) **Random errors :** Random errors in measurement will occur no matter how precise the apparatus is or how careful the person gathering the data is, random errors are purely due to chance and can often be predicted based on statistics.

(e) **Least Count Error :** The Least Count error is the error associated with the resolution of the instrument, the smallest division on the scale of a measuring instrument is called its Least count.

Rule of Thumb : The most accurate that you can measure a quantity is to the last decimal point of a digital meter and half a division on an analogue device such as a ruler.

MEASUREMENT OF ERRORS

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

Relative or Fractional Error:

Relative or Fractional Error

$$= \frac{\text{Mean absolute error}}{\text{Mean value}} = \frac{(\Delta a)_m}{a_m} = \frac{\overline{\Delta a}}{\overline{a}}$$

When the relative error is expressed in percentage, it is known as percentage error,

Percentage error = relative error × 100 or percentage error

$$= \frac{\text{Mean absolute error}}{\text{True value}} \times 100\% = \frac{\overline{\Delta a}}{\overline{a}} \times 100\%$$

Propagation of errors

(a) If x = a + b, then the maximum possible absolute error in measurements of x will be $\Delta x = \Delta a + \Delta b$.

(b) If x = a – b, then the maximum possible absolute error in measurement of x will be $\Delta x = \Delta a + \Delta b$

(c) If $x = \frac{a}{b}$ then the maximum possible fractional error will be

$$\frac{\Delta x}{x} = \frac{\Delta a}{a} + \frac{\Delta b}{b}$$

(d) If $x = a^n$ then the maximum possible fractional error will be

$$\frac{\Delta x}{x} = n\frac{\Delta a}{a}$$

(e) If $x = \frac{a^n b^m}{c^p}$ then the maximum possible fractional error will be $\frac{\Delta x}{x} = n\frac{\Delta a}{a} + m\frac{\Delta b}{b} + p\frac{\Delta c}{c}$

NOTE

* If $R = \frac{R_1R_2}{R_1 + R_2}$.

To find the error in R.

$$R = \frac{X}{Y}, \text{ where } X = R_1R_2 \text{ and } Y = R_1 + R_2.$$

$$\frac{\Delta X}{X} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_2}{R_2} \text{ and } \frac{\Delta Y}{Y} = \frac{\Delta R_1 + \Delta R_2}{R_1 + R_2}$$

$$\frac{\Delta R}{R} = \frac{\Delta X}{X} + \frac{\Delta Y}{Y}$$

Example 5 :

The initial and final temperatures of water as recorded by an observer are (40.6 ± 0.2)°C and (78.3 ± 0.3)°C. Calculate the rise in temperature.

Sol. Given $\theta_1 = (40.6 \pm 0.2)°C$ and $\theta_2 = (78.3 \pm 0.3)°C$

Rise in temperature $\theta = \theta_2 - \theta_1 = 78.3 - 40.6 = 37.7°C$

$$\Delta\theta = \pm(\Delta\theta_1 + \Delta\theta_2) = \pm(0.2 + 0.3) = \pm 0.5°C$$

∴ Rise in temperature = (37.7 ± 0.5)°C

Example 6 :

The error in the measurement of radius of the sphere is 0.3% what is the permissible error in its surface area.

Sol. Surface area of sphere $A = 4\pi r^2$

There is no error involved in constant 4π.

$$\text{Fractional error} = 2\frac{\Delta r}{r}$$

$$\% \text{ error} = \frac{\Delta A}{A} \times 100 = 2 \times \left(\frac{\Delta r}{r} \times 100\right) = 2 \times .3 = 0.6\%$$

Example 7 :

Two resistances are expressed as $R_1 = (4 \pm 0.5)\ \Omega$ and $R_2 = (12 \pm 0.5)\ \Omega$. What is the net resistance when they are connected (i) in series and (iv) in parallel, with percentage error ?

Sol. $R_S = R_1 + R_2 = 16\ \Omega$

$$R_P = \frac{R_1R_2}{R_1 + R_2} = \frac{R_1R_2}{R_S} = 3\ \Omega$$

$$\Delta R_S = \Delta R_1 + \Delta R_2 = 1\ \Omega$$

$$\Rightarrow \frac{\Delta R_S}{R_S} \times 100 = \frac{1}{16} \times 100\%$$

$$\Rightarrow \frac{\Delta R_S}{R_S} \times 100 = 6.25\% \Rightarrow R_S = 16\Omega \pm 6.25\%$$

Similarly, $R_P = \frac{R_1 R_2}{R_S}$

$$\frac{\Delta R_P}{R_P} = \frac{\Delta R_1}{R_1} + \frac{\Delta R_2}{R_2} + \frac{\Delta R_S}{R_S}$$

$$\Rightarrow \frac{\Delta R_P}{R_P} = \frac{0.5}{4} + \frac{0.5}{12} + \frac{1}{16} = 0.23$$

$$\Rightarrow \frac{\Delta R_P}{R_P} \times 100 = 23\% \Rightarrow R_P = 3\Omega \pm 23\%$$

SIGNIFICANT FIGURE

The number of figures required to specify a certain measurement are called significant figure. The last figure of a measurement is always doubtful, put it is included in the number of significant figure. For example, if the length of a pencil measured by suitable scale is 9.48 cm., the number of significant figures in the measurement is 3.

1. The powers of 10 and the zeros on left hand side of a measurement are not counted while counting the number of significant figures.
2. The limit of accuracy of a measuring instrument is equal to the least count of the instrument.
3. In the sum and difference of measurements, the result contains the minimum number of decimal places in the component measurements.
4. In the product and quotient of measurements, the result contains the minimum number of significant figures in the component measurements.
5. Greater is the number of significant figures in a measurement, smaller is the percentage error.
6. If a measurement does not involve the decimal place, then it is confusing while counting the number of significant figures. For example, if a measurement is 4450 m; then we can not surely tell upto what place the measurement is taken; but if it is expressed as 4.450×10^3 m then it is sure that it has been measured upto 4 significant figure.
7. The number of significant figures in a measurement can neither be increased nor decreased. For example if a measurement is written as 5.40 kg; it has significant figure 3; it can not be written as 5.4 or 5.400 kg.

Note : In algebraic operations, the final answer is the same as the minimum number of the significant figures in the physical quantities being operated.
For example : $3.0 \times 800.0 = 2.4 \times 10^3$
The number 3.0 has two significant digits and then number 800.0 has four. The rule states that the answer can have no more than two digits expressed. However the answer as we can all see would be 24200. How do we express the answer 2400 while obeying the rules ? The only way is to express the answer in exponential notation so 2400 could be expressed as : 2.4×10^3.

Rules for rounding off digits :

There are a set of conventional rules for rounding off.

1. Determine according to the rule what the last reported digit should be.
2. Consider the digit to the right of the last reported digit.
3. If the digit to the right of the last reported digit is less than 5 round it and all digits to its right off.
4. If the digit to the right of the last reported digit is greater than 5 round it and all digits to its right off and increased the last reported digit by one.
5. If the digit to the right of the last reported digit is a 5 followed by either no other digits or all zeros, round it and all digits to its right off and if the last reported digit is odd round up to the next even digit. If the last reported digit is even then leave it as is. For example if we wish to round off the following number to 3 significant digits : 18.3682.
   The last reported digits would be the 3. The digit to its right is a 6 which is greater than 5. According to the Rule-4 above, the digit 3 is increased by one and the answer is : 18.4
   Another example : Round off 4.565 to three significant digits.
   The last reported digit would be the 6. The digit to the right is a 5 followed by nothing. Therefore according to Rule-5 above since the 6 is even it remains so and the answer would be 4.56.

TRY IT YOURSELF-2

Q.1 The ΔX is absolute error in the measurement of 'X', ΔY is absolute error in the measurement of Y and ΔQ is absolute error in Q, i.e., product of X and Y, then maximum fractional error in the product of quantities :

(A) $\pm\left(\frac{\Delta X}{X} + \frac{\Delta Y}{Y}\right)$ (B) $\pm\left(\frac{\Delta X}{X} - \frac{\Delta Y}{Y}\right)$

(C) $\pm\left(\frac{\Delta X}{X} \times \frac{\Delta Y}{Y}\right)$ (D) $\pm\left(\frac{\Delta X}{X} / \frac{\Delta Y}{Y}\right)$

Q.2 The density of a cube is measured by measuring its mass and length of its sides. If the maximum errors in the measurement of mass and length are 4% and 3% respectively, the maximum error in the measurement of density would be :
(A) 9% (B) 13% (C) 12% (D) 7%

Q.3 The radius of a ball is (5.2 ± 0.2) cm. The percentage error in the volume of the ball is :
(A) 11% (B) 4% (C) 7% (D) 9%

Q.4 A student performs experiment with simple pendulum and measures time for 10 vibrations. If he measures the time for 100 vibrations, the error in the measurement of time period will be reduced by a factor of :
(A) 10 (B) 90 (C) 100 (D) 1000

Q.5 The length and breadth of a rectangle are (5.7 ± 0.1) cm and (3.4 ± 0.2) cm. The area of rectangle with error limits is approximately:
(A) $(19.4 \pm 1)\ cm^2$ (B) $(19.4 \pm 2)\ cm^2$
(C) $(19.4 \pm 2.5)\ cm^2$ (D) $(19.4 \pm 1.5)\ cm^2$

Q.6 The error in the measurement of radius of the sphere is 0.3%. What is the permissible error in its volume ?
(A) 0.9% (B) 1.2%
(C) 1.8% (D) 2.4%

Q.7 A student finds the constant acceleration of a slowly moving object with a stopwatch. The equation used is $S = (1/2)AT^2$. The time is measured with a stopwatch, the distance, S with a meter stick. What is the acceleration and its estimated error ? $S = 2 \pm 0.005$ meter., $T = 4.2 \pm 0.2$ second.

Q.8 A body travels uniformly a distance of (13.8 ± 0.2) m in a time (4.0 ± 0.3) s. Calculate its velocity with error limits. What is percentage error in velocity?

Q.9 A stone weighs (10.0 ± 0.1) kg in air. The weight of the stone in water is (5.0 ± 0.1) kg. Find the maximum percentage error in the measurement of specific gravity.

Q.10 5.74 g of a substance occupies 1.2 cm^3. Express its density by keeping the significant figures in view.

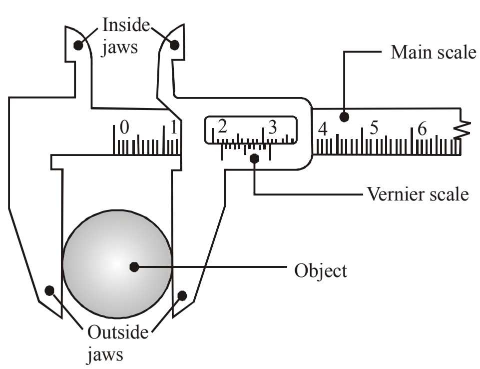
ANSWERS

(1) (A) **(2)** (B) **(3)** (A)
(4) (A) **(5)** (D) **(6)** (A)
(7) 0.23 ± 0.02 m/s^2 **(8)** (3.5 ± 0.31) ms^{-1} , ± 9%
(9) 5% **(10)** 4.8 g cm^{-3}

LEAST COUNT

The smallest value of a physical quantity which can be measured accurately with an instrument is called the least count (L. C.) of the measuring instrument.

Least Count of vernier callipers:



Suppose the size of one main scale division (M.S.D.) is M units and that of one vernier scale division (V. S. D.) is V units. Also let the length of 'a' main scale divisions is equal to the length of 'b' vernier scale divisions.

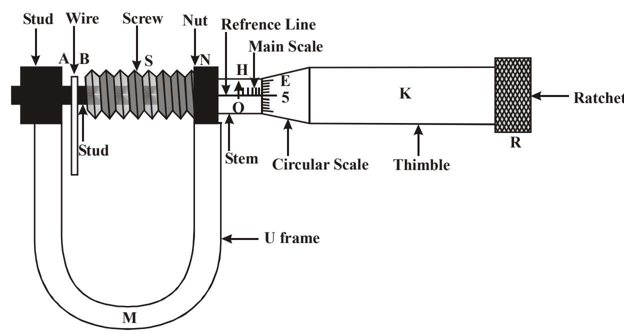
$$aM = bV \quad \text{or} \quad V = \frac{a}{b}M$$

$$\therefore \quad M - V = M - \frac{a}{b}M \qquad \therefore \quad M - V = \left(\frac{b-a}{b}\right)M$$

The quantity (M – V) is called vernier constant (V. C.) or least count (L. C.) of the vernier callipers.

$$L.C. = M - V = \left(\frac{b-a}{b}\right)M$$

Least Count of Screw Gauge:



$$\text{Least Count} = \frac{\text{Pitch}}{\text{Total no. of divisions on the circular disc}}$$

where pitch is defined as the distance moved by the screw head when the circular scale is given one complete rotation,i.e.

$$\text{Pitch} = \frac{\text{Distance moved by the screw on the linear scale}}{\text{No. of full rotations given}}$$

Note : With the decrease in the least count of the measuring instrument, the accuracy of the measurement increases and the error in the measurement decreases.

NOTE Redefining the World's Measurement System

* In a landmark decision, the BIPM's Member States voted on 16 November 2018 to revise the SI (*Système International d'Unités*), changing the world's definition of the kilogram, the ampere, the kelvin and the mole.
* This decision, made at the 26th meeting of the General Conference on Weights and Measures (CGPM), means that from 20 May 2019 all SI units are defined in terms of constants that describe the natural world.
* This will assure the future stability of the SI and open the opportunity for the use of new technologies, including quantum technologies, to implement the definitions.
* **The seven defining constants of the SI**
  - The unperturbed ground state hyperfine transition frequency of the caesium 133 atom $\Delta\nu_{Cs}$ is 9 192 631 770 Hz,
  - Speed of light in vacuum c is 299 792 458 m/s,
  - Planck constant h is $6.626\ 070\ 15 \times 10^{-34}$ J s,
  - Elementary charge e is $1.602\ 176\ 634 \times 10^{-19}$ C
  - Boltzmann constant k is $1.380\ 649 \times 10^{-23}$ J/K
  - Avogadro constant N_A is $6.022\ 140\ 76 \times 10^{23}$ mol^{-1}
  - The luminous efficacy of monochromatic radiation of frequency 540×10^{12} Hz, K_{cd}, is 683 lm/W.

Definition of SI Unit

The Second

* The second is equal to the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the unperturbed ground state of the ^{133}Cs atom. $1\text{s} = \frac{9\,192631770}{\Delta\nu_{Cs}}$

The Meter

* One metre is the length of the path travelled by light in vacuum during a time interval with duration of 1/299,792,458 of a second.

$$1\text{m} = \left(\frac{c}{299792458}\right)\text{s} = \frac{9\,192631770}{299792458}\frac{c}{\Delta\nu_{Cs}}$$

$$\approx 30.663\ 319\frac{c}{\Delta\nu_{Cs}}$$

The Kilogram

* It is defined by taking the fixed numerical value of the Planck constant h to be $6.626\ 070\ 15 \times 10^{-34}$ when expressed in the unit J s, which is equal to kg m^2 s^{-1}, where the metre and the second are defined in terms of c and $\Delta\nu_{Cs}$.

$$1\text{ kg} = \left(\frac{h}{6.62607015 \times 10^{-34}}\right)\text{m}^{-2}\text{s}$$

$$1\text{ kg} = \frac{(299792458)^2}{(6.62607015 \times 10^{-34}) \times (9192\,631770)} \times \frac{h\,\Delta\nu_{Cs}}{c^2}$$

$$\approx 1.475\ 5214 \times 10^{40}\frac{h\,\Delta\nu_{Cs}}{c^2}$$

The Ampere

* One ampere is the electric current corresponding to the flow of $1/(1.602176634 \times 10^{-19})$ elementary charges per second.

$$1\text{A} = \frac{1}{(9192631770) \times (1.602176634 \times 10^{-19})}\Delta\nu_{Cs}\,e$$

$$\approx 6.789\ 687 \times 10^{8}\ \Delta\nu_{Cs}\,e$$

The Kelvin

* One kelvin is equal to the change of thermodynamic temperature that results in a change of thermal energy k T by $1.380\,649 \times 10^{-23}$ J.

$$1\,K = \frac{1.380649 \times 10^{-23}}{(6.62607015 \times 10^{-34}) \times (9192631770)} \times \frac{\Delta\nu_{Cs} h}{k}$$

$$\approx 2.266\,6653 \frac{\Delta\nu_{Cs} h}{k}$$

The Mole

* The mole is the amount of substance of a system that contains $6.022\,140\,76 \times 10^{23}$ specified elementary entities.

$$1\,mol = \frac{6.02214076 \times 10^{23}}{N_A}$$

The Candela

* One candela is the luminous intensity, in a given direction, of a source that emits monochromatic radiation of frequency 540×10^{12} Hz and has a radiant intensity in that direction of (1/683) W/sr.

$$1\,cd = \left(\frac{K_{cd}}{683}\right) Kg\, m^2 s^{-3} sr^{-1}$$

ADDITIONAL EXAMPLES

Example 1 :

In the formula; $N = -D\left[\frac{n_2 - n_1}{x_2 - x_1}\right]$,

D = diffusion coefficient, n_1 and n_2 is number of molecules in unit volume along x_1 and x_2. Which represents distances where N is number of molecules passing through per unit area per unit time Calculate dimensional equation of D.

Sol. By Homogeneity theory of Dimension

$$\text{Dimension of } (N) = \text{Dimension of } D \times \frac{\text{Dimension of } (n_2 - n_1)}{\text{Dimension of } (x_2 - x_1)}$$

$$\frac{1}{L^2 T} = \text{Dimension of } D \times \frac{L^{-3}}{L}$$

$$\Rightarrow \text{Dimension of 'D'} = \frac{L}{L^{-3} \times L^2 T} = \frac{L^2}{T} = L^2 T^{-1}$$

Example 2 :

Find the number of ergs in one Joule.

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

$$n_1 = 1 \cdot \left[\frac{1\,kg}{1\,gm}\right]\left[\frac{1\,m}{1\,cm}\right]^2\left[\frac{1\,sec}{1\,sec}\right]^{-2} = 1\left[\frac{1000\,gm}{1\,gm}\right]\left[\frac{100\,cm}{1\,cm}\right]^{+2}$$

$n_1 = 10^3 . 10^4 = 10^7$ $\quad\therefore$ 1 Joule = 10^7 erg.

Example 3 :

Value of acceleration due to gravity is 9.8 m/sec^2. Find its value in km/hr^2

Sol. $$n_1 = n_2 \left[\frac{L_2}{L_1}\right] \cdot \left[\frac{T_2}{T_1}\right]^{-2}$$

Given $n_2 = 9.8$ therefore, $n_1 = 9.8\left[\frac{1\,m}{1\,km}\right] \cdot \left[\frac{1\,sec}{1\,hr}\right]^{-2}$

$$= 9.8\left[\frac{1\,m}{1000\,m}\right] \cdot \left[\frac{1\,sec}{60 \times 60\,sec}\right]^{-2}$$

$$n_1 = 9.8\left[\frac{1}{1000} \times 60 \times 60 \times 60 \times 60\right] = 98 \times 36 \times 36 = 127008$$

$\therefore$ g = 127008 km/hr^2

Example 4 :

Density of oil is 0.8 gm/cm^3. Find its value in MKS system.

Sol. $$n_1 = n_2 \cdot \left[\frac{M_2}{M_1}\right]\left[\frac{L_2}{L_1}\right]^{-3} = 0.8 \cdot \left[\frac{1\,gm}{1\,kg}\right] \cdot \left[\frac{1\,cm}{1\,m}\right]^{-3}$$

or, $$n_1 = 0.8 \cdot \left[\frac{1\,gm}{1000\,gm}\right] \cdot \left[\frac{1\,cm}{100\,cm}\right]^{-3}$$

or $n_1 = 0.8 \times 10^3$

$\therefore$ Density of oil is 0.8×10^3 kg/m^3 in MKS system.

Example 5 :

The kinetic energy of rotation k depends on the angular momentum J and moment of inertia I. Find the expression for Kinetic Energy.

Sol. Let $K \propto J^a I^b$ then $K = C . J^a I^b$ ......(i)

Writing dimensions on both the sides, we get

$[M L^2 T^{-2}] = [M L^2 T^{-1}]^a . [M L^2]^b$

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

Comparing powers of T, we get

$-a = -2$ or $a = 2$

Comparing powers of M, we get

$a + b = 1$ or $2 + b = 1$ or $b = -1$

Putting these values of 'a' and 'b' in eq. (i), we get

$K = \frac{C.J^2}{I}$. The value of constant C cannot be found.

Example 6 :

If $T = 2\pi\sqrt{\frac{ML^3}{3\,Yq}}$ then find the dimensions of q. Where T is the time period of bar of mass M, length L & Young modulus Y.

Sol. $T = 2\pi\sqrt{\frac{ML^3}{3\,Yq}}$, writing dimensions of both the sides, we

get $[T] = \left[\frac{ML^3}{ML^{-1}T^{-2}q}\right]^{1/2}$ or $q = [L^4]$

Example 7 :

The resistance R = V/I where V = (100 ± 5)V and I = (10 ± 0.2)A. Find the percentage error in R.

Sol. The percentage error in V is $\frac{5}{100}\times 100\% = 5\%$

and in I it is $\frac{0.2}{10}\times 100\% = 2\%$.

The total error in R would therefore be 5% + 2% = 7%.

Example 8 :

The period of oscillation of a simple pendulum is $2\pi\sqrt{L/g}$. Measured value of L is 20.0 cm known to 1 mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1s resolution. What is the accuracy in the determination of g ?

Sol. $g = 4\pi^2 L/T^2$

Here, $T = \frac{t}{n}$ & $\Delta T = \frac{\Delta t}{n}$. Therefore, $\frac{\Delta T}{T} = \frac{\Delta t}{t}$.

The errors in both L and t are the least count errors.

$$(\Delta g/g) = (\Delta L/L) + 2\,(\Delta T/T) = \frac{0.1}{20.0} + 2\left(\frac{1}{90}\right) = 0.027$$

Thus, the percentage error in g is,

$$100\,(\Delta g/g) = 100\,(\Delta L/L) + 2 \times 100\,(\Delta T/T) = 3\%$$

Example 9 :

The main scale of a vernier callipers reads 10mm in 10 divisions. 10 divisions of Vernier scale coincide with 9 divisions of the main scale. When the two jaws of the callipers touch each other, the fifth division of the vernier coincides with 9main scale divisions and the zero of the vernier is to the right of zero of main scale. When a cylinder is tightly placed between the two jaws, the zero of vernier scale lies slightly to the left of 3.2 cm and the fourth vernier division coincides with a main scale division the diameter of the cylinder is

(A) 3.09 cm (B) 3.14 cm

(C) 3.04 cm (D) none of these

Sol.

(A). Zero error = 0.5 mm = 0.05 m

Observed reading of cylinder

= 3.1 cm + (4) (0.01 cm) = 3.14 cm

Actual thickness of cylinder

= (3.14) – (0.05) = 3.09 cm

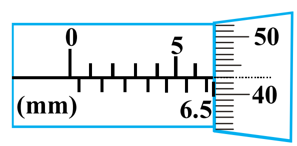
Example 10:

Read the screwgauge

* Main scale has $\frac{1}{2}$ mm marks.

* Circular scale has 50 division.

* In complete rotation, the screw advances by $\frac{1}{2}$ mm.



Sol.

Object thickness = $6.5\text{mm} + 43\left(\frac{1/2\text{ mm}}{50}\right)$

= 6.93 mm

QUESTION BANK

CHAPTER 2 : UNITS AND MEASUREMENTS

EXERCISE - 1 [LEVEL-1]

Choose one correct response for each question.

PART - 1 : PHYSICAL WORLD

Q.1 Which of the following does not depict the correct link between technology and physics?

(A) Photocell – Photoelectric effect
(B) Rocket propulsion – Laws of thermodynamics
(C) Optical fibres – Total internal reflection of light
(D) Fusion test reactor – Magnetic confinement of plasma

Q.2 I. Conservation laws have a deep connection with symmetries of nature.
II. Space is heterogeneous and there is no preferred location in the universe.
Which of the following statement(s) is/are false?
(A) Only I (B) Only II
(C) Both I and II (D) None of the above

Q.3 Force of friction and tension in a string are
(A) gravitational forces (B) electromagnetic forces
(C) nuclear forces (D) weak forces

Q.4 Arrange the following basic forces in the increasing order of relative strength
1. Gravitational force 2. Electromagnetic force
3. Weak nuclear force 4. Strong nuclear force
(A) 1, 2, 3, 4 (B) 1, 3, 2, 4
(C) 4, 3, 2, 1 (D) 4, 1, 2, 3

Q.5 Which of the following statements constitutes a scientific hypothesis?
(i) Atoms are the smallest particles of matter that exist.
(ii) Space is permeated with a substance that is undetectable.
(A) Only (i) (B) Only (ii)
(C) Both (i) and (ii) (D) None of these

Q.6 Which of the following statement(s) is/are correct?
I. Symmetry of laws of nature w.r.t. translation in space gives rise to conservation of linear momentum.
II. Isotropy of space underlies the law of conservation of angular momentum.
III. Symmetry of space and time plays a vital role in modern theories in nature.
(A) Only I (B) Only II
(C) Both II and III (D) All of the above

PART - 2 : UNITS

Q.7 Which of the following is the smallest unit?
(A) millimetre (B) angstrom
(C) fermi (D) metre

Q.8 In $S = a + bt + ct^2$, S is measured in metres and t in seconds. The unit of c is –
(A) None (B) m
(C) ms^{-1} (D) ms^{-2}

Q.9 The unit of surface tension in SI system is
(A) Dyne/cm^2 (B) Newton/m
(C) Dyne/cm (D) Newton/m^2

Q.10 The velocity of a particle depends upon as $v = a + bt + ct^2$; if the velocity is in m/sec, the unit of a will be
(A) m/sec (B) m/sec^2
(C) m^2/sec (B) m/sec^3

Q.11 Unit of impulse is –
(A) Newton (B) kg-m
(C) kg-m/s (D) Joule

Q.12 Which of the following is not a unit of time –
(A) Leap year (B) Micro second
(C) Lunar month (D) Light year

Q.13 1 parsec is approximately equal to (where AU is astronomical unit)
(A) 2×10^5 AU (B) 2×10^6 AU
(C) 2×10^8 AU (D) 2×10^{10} AU

Q.14 What are the SI units of power?
(A) m/s^2 (B) kg-m/s^2
(C) kg-m^2/s^2 (D) kg-m^2/s^3

Q.15 The SI standard of measurement for which of the following fundamental quantities is not based on a universally constant measurement ?
(A) time (B) length
(C) mass (D) luminous intensity

Q.16 The surface tension of a liquid is 70 dyne/cm. In MKS system its value is.
(A) 70 N/m (B) 7×10^{-2} N/m
(C) 7×10^3 N/m (D) 7×10^2 N/m

Q.17 kWh is a unit of :
(A) Power (B) Energy
(C) Force (D) Temperature

PART - 3 : DIMENSIONS

Q.18 The dimensional formula $M^0L^2T^{-2}$ stands for
(A) Torque
(B) Angular momentum
(C) Latent heat
(D) Coefficient of thermal conductivity

Q.19 For a body moving along x-axis, the distance travelled by body from a reference point is given as function of time t as $x = at^2 + b$, where a and b are constants, then the dimension of $\sqrt{ab}$ is same as –
(A) Speed (B) Distance travelled
(C) Acceleration (D) None of these

Q.20 The position (x) of a particle depends on a velocity (v) and time (t) as given by relation $x = Av + \frac{B}{A+t}$.
Find dimension of AB.
(A) $[LT^3]$ (B) $[L^{-1}T^2]$
(C) $[LT^1]$ (D) $[LT^2]$

Q.21 If P, Q, R are physical quantities, having different dimensions, which of the following combinations can never be a meaningful quantity?
(A) $\frac{(P-Q)}{R}$ (B) $PQ-R$ (C) $\frac{PQ}{R}$ (D) $\frac{(PR-Q^2)}{R}$

Q.22 What are the dimensions of energy?
(A) $[L][T^{-2}]$ (B) $[M][L][T^{-2}]$
(C) $[M][L^2][T^{-2}]$ (D) $[M][L^2][T^{-3}]$

Q.23 If area (A), velocity (v) and density (ρ) are base units, then the dimensional formula of force –
(A) $Av\rho$ (B) $Av^2\rho$
(C) $Av\rho^2$ (D) $A^2v\rho$

Q.24 E, m, J and G denote energy, mass, angular momentum and gravitational constant respectively, then the dimension of $\frac{EJ^2}{m^5G^2}$ are
(A) Angle (B) Length
(C) Mass (D) Time

Q.25 The dimensions of physical quantity X in the equation Force $= \frac{X}{\text{Density}}$ is given by.
(A) $M^1L^4T^{-2}$ (B) $M^2L^{-2}T^{-1}$
(C) $M^2L^{-2}T^{-2}$ (D) $M^1L^{-2}T^{-1}$

Q.26 With the usual notations, the following equation $S_t = u + \frac{1}{2}a(2t-1)$ is.
(A) Only numerically correct .
(B) Only dimensionally correct.
(C) Both numerically and dimensionally correct.
(D) Neither numerically nor dimensionally correct.

Q.27 In the relation : $\frac{dy}{dx} = 2\omega \sin(\omega t + \phi_0)$ the dimensional formula for $(\omega t + \phi_0)$ is :
(A) MLT (B) MLT^0
(C) ML^0T^0 (D) $M^0L^0T^0$

PART - 4 : MEASUREMENT

Q.28 The mean length of an object is 5 cm. Which of the following measurements is most accurate?
(A) 4.9 cm (B) 4.805 cm
(C) 5.25 cm (D) 5.4 cm

Q.29 Which of the following time measuring device is most precise?
(A) A wall clock (B) A stop watch
(C) A digital watch (D) An atomic clock

Q.30 A physical quantity X is related to four measurable quantities a, b, c and d as follows
$X = a^2b^3c^{5/2}d^{-2}$
The percentage error in the measurement of a, b, c and dare 1%, 2%, 2% and 4% respectively. What is the percentage error in quantity X ?
(A) 15% (B) 17%
(C) 21% (D) 23%

Q.31 Name the device used for measuring the mass of atoms and molecules.
(A) Spectrograph (B) Photograph
(C) Cryptograph (D) Radiograph

Q.32 The number of significant figures in 0.06900 is
(A) 5 (B) 4
(C) 2 (D) 3

Q.33 Which of the following is the most precise instrument for measuring length?
(A) Metre rod of least count 0.1 cm.
(B) Vernier callipers of least count 0.01 cm.
(C) Screw gauge of least count 0.001 cm.
(D) None of these

Q.34 Which of the following measurements is most precise?
(A) 5.00 mm (B) 5.00 cm
(C) 5.00 m (D) 5.00 km.

Q.35 The Sun is a hot plasma (ionized matter) with its inner core at a temperature exceeding 10^7K and its outer surface at a temperature of about 6000K. The mass density of the Sun is – [Mass of the Sun = 2.0×10^{30} kg and radius of the Sun = 7.0×10^8 m]
(A) 2×10^3 kg / m^3 (B) 1.4×10^3 kg / m^3
(C) 4×10^6 kg / m^3 (D) 7×10^3 kg / m^3

Q.36 The radius of a sphere is 1.41. Its volume to an appropriate number of significant figures is
(A) 11.73 cm^3 (B) 11.736 cm^3
(C) 11.7 cm^3 (D) 117 cm^3

Q.37 1 amu (Atomic mass unit) =
(A) 1.67×10^{-27} kg (B) 2.03×10^{-23} kg
(C) 4.02×10^{-28} kg (D) 3.02×10^{-24} kg

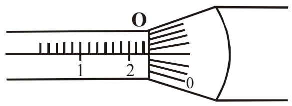
Q.38 The sum of the numbers 436.32, 227.2 and 0.301 in appropriate significant figures is
(A) 663.821 (B) 664
(C) 663.8 (D) 663.82

Q.39 The least count of vernier calliper is 0.1mm. The main scale reading before the zero of the vernier scale is 10 and zeroth division of the vernier scale coincides with the main scale division. Given that each main scale division is 1mm. The radius is –
(A) 0.01 cm. (B) 0.1 cm.
(C) 0.5 cm. (D) 0.05 cm.

Q.40 In a screw gauge, there are 8 divisions in a distance of 2mm on linear scale. The total number of divisions on circular scale is 250. While measuring the diameter of a wire the linear scale reads 15 divisions and 100th division of circular scale coincides with reference line of linear scale. The observed value of diameter of the wire is –
(A) 15.100 mm (B) 30.1 mm
(C) 3.75 mm (D) 3.850 mm

Q.41 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 & 47th division on the circular scale coincides with the reference line. The length of the wire is 5.6 cm. The curved surface area (in cm^2) of the wire in appropriate number of significant figures -
(A) 2.4 (B) 2.5 (C) 2.6 (D) 2.7

Q.42 Zero correction as per given figure of a standard screw gauge is -



(A) 0.002 cm (B) – 0.002 cm
(C) – 0.003 cm (D) 0.003 cm

Q.43 The pitch of a screw gauge is 1 mm and there are 100 divisions on the cap. When nothing is placed in between its jaws, it reads –5 divisions. When a wire is held there, the reading on the main scale is 2 mm and 69 division on its cap. If the length of wire is 20 cm, the volume in mm^3 will be
(A) 2.74×10^3 (B) 2.69×10^3
(C) 1.18×10^3 (D) 1.88×10^3

PART - 5 : MISCELLANEOUS

Q.44 In a system of units if force (F), acceleration (A) and time (T) are taken as fundamental units then the dimensional formula of energy is –
(A) FA^2T (B) FAT^2
(C) F^2AT (D) FAT

Q.45 If e is charge, V is potential difference, T is temperature, then units of $\frac{eV}{T}$ are same as of –
(A) Planck's constant (B) Stefan's constant
(C) Boltzman constant (D) Gravitational constant

Q.46 Two masses M_A and M_B ($M_A < M_B$) are weighed using same weighing machine. Absolute error and relative error in two measurement are (Assume only systematic errors are involved)
(A) Absolute error same for both, relative error greater for M_A and lesser for M_B.
(B) Absolute error same for both, relative error greater for M_B and lesser for M_A.
(C) Relative error same for both, absolute error greater for M_A and lesser for M_B.
(D) Relative error same for both, absolute error greater for M_B and lesser for M_A.

Q.47 The length and breadth of a rectangular sheet are 16.2 cm and 10.1cm, respectively. The area of the sheet in appropriate significant figures and error is –
(A) $164 \pm 3\ cm^2$ (B) $163.62 \pm 2.6\ cm^2$
(C) $163.6 \pm 2.6\ cm^2$ (D) $163.62 \pm 3\ cm^2$

Q.48 A stone weighs (10.0 ± 0.1) kg in air. The weight of the stone in water is (5.0 ± 0.1) kg. Find the maximum percentage error in the measurement of specific gravity.
(A) 2% (B) 3%
(C) 4% (D) 5%

Q.49 You measure two quantities as $A = 1.0\ m \pm 0.2m$, $B = 2.0\ m \pm 0.2\ m$. We should report correct value for $\sqrt{AB}$ as:
(A) $1.4\ m \pm 0.4\ m$ (B) $1.41m \pm 0.15\ m$
(C) $1.4m \pm 0.3\ m$ (D) $1.4m \pm 0.2\ m$

Q.50 A vernier callipers having 1 main scale division = 0.1cm 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

EXERCISE - 2 [LEVEL-2]

Choose one correct response for each question.

Q.1 A suitable unit for gravitational constant is –
(A) kg-m sec^{-1} (B) Nm^{-1} sec
(C) $Nm^2\ kg^{-2}$ (D) None of these

Q.2 The unit of Stefan's constant σ is –
(A) $Wm^{-2}K^{-1}$ (B) $Wm^{-2}K^{-3}$
(C) $Wm^{-2}K^{-4}$ (D) $Wm^{-2}K^4$

Q.3 Curie is a unit of –
(A) Energy of γ-rays (B) Half life
(C) Radioactivity (D) Intensity of γ-rays

Q.4 The equation $\left(P + \frac{a}{V^2}\right)(V - b)$ = constant. The units of a are
(A) Dyne × cm^5 (B) Dyne × cm^4
(C) Dyne × cm^3 (D) Dyne × cm^2

Q.5 In a Vernier Calipers (VC), N divisions of the main scale coincide with N + m divisions of the vernier scale. What is the value of m for which the instrument has minimum least count?
(A) 1 (B) N
(C) Infinity (D) N/2

Q.6 The pitch of a screw gauge is 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.
(A) 1.84 mm (B) 2.84 mm
(C) 3.84 mm (D) 4.84 mm

Q.7 Measure of two quantities along with the precision of respective measuring instrument is
$A = 2.5\ m\ s^{-1} \pm 0.5\ m\ s^{-1}$, $B = 0.10\ s \pm 0.01\ s$
The value of A B will be
(A) (0.25 ± 0.08) m (B) (0.25 ± 0.5) m
(C) (0.25 ± 0.05) m (D) (0.25 ± 0.135) m

Q.8 The value of resistance is 10.845Ω and the current is 3.23 A. On multiplying, we get the potential difference is 35.02935 V. The value of potential difference in terms of significant figures would be –
(A) 35 V (B) 35.0 V
(C) 35.029 V (D) 35.03 V

Q.9 The numbers 2.745 and 2.735 on rounding off to 3 significant figures will give
(A) 2.75 and 2.74 (B) 2.74 and 2.73
(C) 2.75 and 2.73 (D) 2.74 and 2.74

Q.10 The dimensions of 'resistance' are same as those of ……… where h is the Planck's constant, e is the charge.
(A) h^2/e^2 (B) h^2/e
(C) h/e^2 (D) h/e

Q.11 If C be the capacitance and V be the electric potential, then the dimensional formula of CV^2 is –
(A) $M^1 L^{-3} T^1 A^1$ (B) $M^0 L^1 T^{-2} A^0$
(C) $M^1 L^1 T^{-2} A^{-1}$ (D) $M^1 L^2 T^{-2} A^0$

Q.12 The dimensional formula of physical quantity is $M^a L^b T^c$. Then that physical quantity is –
(A) force if a = 1, b = 1, c = 2
(B) angular frequency if a = 0, b = 0, c = –1
(C) spring constant if a = 1, b = –1, c = –2
(D) surface tension if a = 1, b = 1, c = –2

Q.13 Which one of the following is NOT correct?
(A) Dimensions of thermal conductivity is $M^1L^1T^{-3}K^{-1}$
(B) Dimensional formula of potential (V) is $M^1L^2T^3A^{-1}$
(C) Dimensions of permeability of free space (μ_0) is $M^1L^1T^{-2}A^{-2}$
(D) Dimensional formula of RC is $M^0L^0T^1$

Q.14 A physical quantity Q is found to depend on observables x, y and z, obeying relation $Q = \frac{x^3y^2}{z}$. The percentage error in the measurements of x, y and z are 1%, 2% and 4% respectively. What is percentage error in the quantity Q?
(A) 4% (B) 3%
(C) 11% (D) 1%

Q.15 The dimensions of universal gravitational constant are
(A) $M^{-2}L^2T^{-1}$ (B) $M^{-1}L^3T^{-2}$
(C) ML^2T^{-1} (D) $M^{-2}L^3T^{-2}$

Q.16 Using m, ℓ and t as the symbols for the dimension of mass, length and time, what are the dimensions of force and momentum?
(A) $[F] = m\,\ell\,t^{-1}$; $[p] = m\,\ell\,t^{-1}$
(B) $[F] = m\,\ell\,t^{-2}$; $[p] = m\,\ell\,t^{-1}$
(C) $[F] = m\,\ell^{-1}\,t^{-2}$; $[p] = m\,\ell\,t^{-2}$
(D) $[F] = m^2\,\ell\,t^{-2}$; $[p] = m\,\ell^2\,t^{-1}$

Q.17 A mass M is suspended from a string of length L in a gravitational field g. The mass swings back and forth on a plane at the end of the fixed-length string. Use dimensional analysis to determine how the period of oscillation depends on M, L and g.
(A) $T \propto \sqrt{\frac{L}{g}}$ (B) $T \propto \sqrt{\frac{ML}{g}}$
(C) $T \propto \sqrt{\frac{L}{g^2}}$ (D) $T \propto \sqrt{\frac{L^2}{M}}$

Q.18 If velocity v, acceleration a and density ρ are taken as fundamental quantities, then find the dimensional formula for kinetic energy K.
(A) $[v^7a^{-3}\rho^1]$ (B) $[v^8a^{-2}\rho^1]$
(C) $[v^8a^{-3}\rho^1]$ (D) $[v^2a^{-1}\rho^1]$

Q.19 In relation $N = \frac{\alpha}{\beta}e^{-\alpha E/t}$, N is the number of nuclei, E is energy and t is time. Find dimension of α and β.
(A) $[M^1L^{-2}T^3]$ (B) $[M^{-1}L^{-2}T^3]$
(C) $[M^1L^2T^3]$ (D) $[M^{-1}L^2T^2]$

Q.20 If pressure P, velocity V and time T are taken as fundamental physical quantities, the dimensional formula of force is
(A) PV^2T^2 (B) $P^{-1}V^2T^{-2}$
(C) PVT^2 (D) $P^{-1}VT^2$

Q.21 The ΔX is absolute error in the measurement of 'X', ΔY is absolute error in the measurement of Y and ΔQ is absolute error in Q, i.e., product of X and Y, then maximum fractional error in the product of quantities :
(A) $\pm\left(\frac{\Delta X}{X}+\frac{\Delta Y}{Y}\right)$ (B) $\pm\left(\frac{\Delta X}{X}-\frac{\Delta Y}{Y}\right)$
(C) $\pm\left(\frac{\Delta X}{X}\times\frac{\Delta Y}{Y}\right)$ (D) $\pm\left(\frac{\Delta X}{X}/\frac{\Delta Y}{Y}\right)$

Q.22 The length and breadth of a rectangle are (5.7 ± 0.1) cm and (3.4 ± 0.2) cm. The area of rectangle with error limits is approximately:
(A) (19.4 ± 1) cm^2 (B) (19.4 ± 2) cm^2
(C) (19.4 ± 2.5) cm^2 (D) (19.4 ± 1.5) cm^2

Q.23 A student finds the constant acceleration of a slowly moving object with a stopwatch. The equation used is $S = (1/2)\,AT^2$. The time is measured with a stopwatch, the distance, S with a meter stick. What is the acceleration with estimated error ? S = 2 ± 0.005 meter, T = 4.2 ± 0.2 second.
(A) 0.23 ± 0.01 m/s^2 (B) 0.32 ± 0.02 m/s^2
(C) 0.23 ± 0.002 m/s^2 (D) 0.23 ± 0.02 m/s^2

Q.24 5.74 g of a substance occupies 1.2 cm^3. Express its density by keeping the significant figures in view.
(A) 4.80 g cm^{-3} (B) 4.79 g cm^{-3}
(C) 4.8 g cm^{-3} (D) 4.08 g cm^{-3}

Q.25 A highly rigid cubical block A of small mass M and side L is fixed rigidly onto another cubical block B of the same dimensions and of low modulus of rigidity η such that the lower face of A completely covers the upper face of B. The lower face of B rigidly held on a horizontal surface. A small force F is applied perpendicular to one of the side faces of A. After the force is withdrawn block A executes small oscillations. The time period of which is given by.
(A) $2\pi\sqrt{\frac{M\eta}{L}}$ (B) $2\pi\sqrt{\frac{L}{M\eta}}$
(C) $2\pi\sqrt{\frac{ML}{\eta}}$ (D) $2\pi\sqrt{\frac{M}{\eta L}}$

Q.26 The volume of a liquid of density ρ and viscosity η flowing in time t through a capillary tube of length ℓ and radius R, with a pressure difference P, across its ends is proportional to :
(A) $P^2R^2t/\eta\ell^2$ (B) $PR^4/\eta\ell t$
(C) $PR^4t/\eta\ell$ (D) $\eta R^4/\ell t$

Q.27 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

Q.28 Which one of the following groups have quantities that do not have the same dimensions
(A) Pressure, stress (B) Velocity, speed
(C) Force, impulse, (D) Work, energy

Q.29 The dimensions of Planck's constant are same as –
(A) Energy (B) Power
(C) Momentum (D) Angular momentum

Q.30 The unit of permittivity of free space, ε_0 is –
(A) Coulomb^2/(Newton-metre)^2
(B) Coulomb/Newton-metre
(C) Newton-metre^2/ Coulomb^2
(D) Coulomb^2/Newton-metre^2

Q.31 In C.G.S. system the magnitutde of the force is 100 dynes. In another system where the fundamental physical quantities are kilogram, metre and minute, the magnitude of the force is
(A) 0.036 (B) 0.36
(C) 3.6 (D) 36

Q.32 The unit of L/R is (where L = inductance & R = resistance)
(A) sec (B) sec^{-1}
(C) Volt (D) Ampere

Q.33 The velocity of water waves v may depend upon 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 as –
(A) $v^2 \propto \lambda g^{-1}\rho^{-1}$ (B) $v^2 \propto g\lambda\rho$
(C) $v^2 \propto g\lambda$ (D) $v^2 \propto g^{-1}\lambda^{-3}$

Q.34 If C and L denote capacitance and inductance respectively, then the dimensions of LC are –
(A) $M^0L^0T^0$ (B) $M^0L^0T^2$
(C) $M^2L^0T^2$ (D) MLT^2

Q.35 The period of a body under SHM i.e. presented by $T = P^aD^bS^c$; where P is pressure, D is density and S is surface tension. The value of a, b and c are –
(A) $-\frac{3}{2}, \frac{1}{2}, 1$ (B) –1, –2, 3
(C) $\frac{1}{2}, -\frac{3}{2}, -\frac{1}{2}$ (D) $1, 2, \frac{1}{3}$

Q.36 μ_0 and ε_0 denote the permeability and permittivity of free space, the dimensions of $\mu_0\varepsilon_0$ are –
(A) LT^{-1} (B) $L^{-2}T^2$
(C) $M^{-1}L^{-3}Q^2T^2$ (D) $M^{-1}L^{-3}I^2T^2$

Q.37 If P represents radiation pressure, c represents speed of light and Q represents radiation energy striking a unit area per second, then non-zero integers x, y and z such that $P^xQ^yc^z$ is dimensionless, are–
(A) x = 1, y = 1, z = –1 (B) x = 1, y = –1, z = 1
(C) x = –1, y = 1, z = 1 (D) x = 1, y = 1, z = 1

Q.38 If velocity v, acceleration A and force F are chosen as fundamental quantities, then the dimensional formula of angular momentum in terms of v, A and F would be
(A) $FA^{-1}v$ (B) Fv^3A^{-2}
(C) Fv^2A^{-1} (D) $F^2v^2A^{-1}$

Q.39 If the time period (T) of vibration of a liquid drop depends on surface tension (S), radius (r) of the drop and density (ρ) of the liquid, then the expression of T is
(A) $T = k\sqrt{\rho r^3/S}$ (B) $T = k\sqrt{\rho^{1/2}r^3/S}$
(C) $T = k\sqrt{\rho r^3/S^{1/2}}$ (D) None of these

EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)

NOTE : The answer to each question is a NUMERICAL VALUE.

Q.1 To find the distance d over which a signal can be seen clearly in foggy conditions, a railways-engineer uses dimensional 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 finds that d is proportional to $S^{1/n}$. The value of n is

Q.2 The moment of inertia of a body rotating about a given axis is 6.0 kg m^2 in the SI system. The value of the moment of inertia in a system of units in which the unit of length is 5 cm and the unit of mass is 10 g is 2.4×10^X. Find the value of X.

Q.3 The heat generated in a circuit is given by $H = I^2Rt$ joule 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. The maximum % error in measuring heat will be-

Q.4 The length of a cylinder is measured with a metre rod having least count 0.1 cm. Its diameter is measured with vernier callipers having least count 0.01 cm. Given that length is 5.0 cm and radius is 2.00 cm. The percentage error in the calculated value of the volume will be :

EXERCISE - 4 [PREVIOUS YEARS AIEEE / JEE MAIN QUESTIONS]

Q.1 The pairs having same dimensional formula
(A) Angular momentum, torque **[AIEEE-2002]**
(B) Torque, work
(C) Plank's constant, boltzman's constant
(D) Gas constant, pressure

Q.2 The physical quantities not having same dimensions are – **[AIEEE-2003]**
(A) Momentum and Planck's constant
(B) Stress and Young's modulus
(C) Speed and $(\mu_0\varepsilon_0)^{-1/2}$
(D) Torque and work

Q.3 Dimensions of $\frac{1}{\mu_0\varepsilon_0}$, where symbols have their usual meaning, are – **[AIEEE-2003]**
(A) $[L^{-2}T^2]$ (B) $[L^2T^{-2}]$
(C) $[LT^{-1}]$ (D) $[L^{-1}T]$

Q.4 Which one of the following represents the correct dimensions of the coefficient of viscosity **[AIEEE-2004]**
(A) $ML^{-1}T^{-2}$ (B) MLT^{-1}
(C) $ML^{-1}T^{-1}$ (D) $ML^{-2}T^{-2}$

Q.5 Out of the following pair, which one does NOT have identical dimensions is **[AIEEE-2005]**
(A) angular momentum and Planck's constant
(B) impulse and momentum
(C) moment of inertia and moment of a force
(D) work and torque

Q.6 Which of the following units denotes the dimensions ML^2/Q^2, where Q denotes the electric charge – **[AIEEE 2006]**
(A) H/m^2 (B) Weber (Wb)
(C) Wb/m^2 (D) Henry (H)

Q.7 The dimension of magnetic field in M, L, T and C (Coulomb) is given as **[AIEEE-2008]**
(A) MT^2C^{-2} (B) $MT^{-1}C^{-1}$
(C) $MT^{-2}C^{-1}$ (D) $MLT^{-1}C^{-1}$

Q.8 Let $[\epsilon_0]$ denote the dimensional formula of the permittivity of vacuum. If M = mass, L = length, T = time and A = electric current, then : **[JEE MAIN 2013]**
(A) $[\epsilon_0] = [M^{-1}L^{-3}T^2A]$ (B) $[\epsilon_0] = [M^{-1}L^{-3}T^4A^2]$
(C) $[\epsilon_0] = [M^{-1}L^2T^{-1}A^{-2}]$ (D) $[\epsilon_0] = [M^{-1}L^2T^{-1}A]$

Q.9 A student measured the length of a rod and wrote it as 3.50cm. Which instrument did he use to measure it?
(A) A screw gauge having 100 divisions in the circular scale and pitch as 1 mm. **[JEE MAIN 2014]**
(B) A screw gauge having 50 divisions in the circular scale and pitch as 1 mm.
(C) A meter scale.
(D) A vernier calliper where the 10 divisions in vernier scale matches with 9 division in main scale and main scale has 10 divisions in 1 cm.

Q.10 The period of oscillation of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$. Measured value of L is 20.0 cm known to 1mm accuracy and time for 100 oscillations of the pendulum is found to be 90 s using a wrist watch of 1 s resolution. The accuracy in the determination of g is
(A) 3% (B) 1% **[JEE MAIN 2015]**
(C) 5% (D) 2%

Q.11 A student measures the time period of 100 oscillations of a simple pendulum four times. The data set is 90s, 91s, 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) $92 \pm 5.0s$ (B) $92 \pm 1.8s$
(C) $92 \pm 3s$ (D) 92 ± 2 s

Q.12 A screw gauge with a pitch of 0.5 mm and a circular scale with 50 divisions is used to measure the thickness of a 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) 0.80 mm (B) 0.70 mm
(C) 0.50 mm (D) 0.75 mm

Q.13 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) 4.5% (B) 6%
(C) 2.5% (D) 3.5%

Q.14 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]**
(A) 5.755 m (B) 5.725 mm
(C) 5.740 m (D) 5.950 mm

Q.15 Expression for time in terms of G (universal gravitational constant), h (Planck constant) and c (speed of light) is proportional to : **[JEE MAIN 2019 (JAN)]**
(A) $\sqrt{\frac{Gh}{c^3}}$ (B) $\sqrt{\frac{hc^5}{G}}$
(C) $\sqrt{\frac{c^3}{Gh}}$ (D) $\sqrt{\frac{Gh}{c^5}}$

Q.16 In SI units, the dimesions 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) $AT^{-3}ML^{3/2}$

Q.17 In a simple pendulum experiment for determination of acceleration due to gravity (g), time taken for 20 oscillations is measured by using a watch of 1 second least count. The mean value of time taken comes out to be 30 s. The length of pendulum is measured by using a meter scale of least count 1mm and the value obtained is 55.0 cm. The percentage error in the determination of g is close to : **[JEE MAIN 2019 (APRIL)]**

(A) 0.7%
(B) 0.2%
(C) 3.5%
(D) 6.8%

Q.18 If surface tension (S), Moment of inertia (I) and Planck's constant (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) $S^{1/2}I^{3/2}h^{-1}$

Q.19 Find the dimension of $\frac{B^2}{2\mu_0}$, where B is magnetic field and μ_0 is the magnetic permeability of vacuum, is:

[JEE MAIN 2020 (JAN)]

(A) $ML^{-1}T^{-2}$
(B) ML^2T^{-2}
(C) $ML^{-1}T^2$
(D) $ML^{-2}T^{-1}$

Q.20 The dimension of stopping potential V_0 in photoelectric effect in units of Planck's constant 'h', speed of light 'c' and Gravitational constant 'G' and ampere A is :

[JEE MAIN 2020 (JAN)]

(A) $h^2 G^{3/2} c^{1/3} A^{-1}$
(B) $h^{-2/3} c^{-1/3} G^{4/3} A^{-1}$
(C) $h^{1/3} G^{2/3} c^{1/3} A^{-1}$
(D) $h^0c^5G^{-1}A^{-1}$

Q.21 A simple pendulum is being used to determine the value of gravitational acceleration g at a certain place. Th 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 (JAN)]**

(A) 3.40%
(B) 5.40%
(C) 4.40%
(D) 2.40%

Q.22 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 (JAN)]

(A) Momentum
(B) Area
(C) Energy
(D) Volume

Q.23 If the screw on a screw-gauge is given six rotations, it moves by 3 mm on the main scale. If there are 50 divisions on the circular scale the least count of the screw gauge is **[JEE MAIN 2020 (JAN)]**

(A) 0.001 mm
(B) 0.001 cm
(C) 0.02 mm
(D) 0.01 cm

EXERCISE - 5 (PREVIOUS YEARS AIPMT/NEET EXAM QUESTIONS)

Choose one correct response for each question.

Q.1 The ratio of the dimension of Placnk's constant and that of the moment of inertia is the dimension of – **[AIPMT 2005]**

(A) time (B) frequency
(C) angular momentum (D) velocity

Q.2 The velocity v of a particle at time t is given by

$v = at + \frac{b}{t+c}$, where a, b and c are constant. The dimensions of a, b and c are respectively **[AIPMT 2006]**

(A) L^2, T and LT^2 (B) LT^2, LT and L (C) L, LT and T^2 (D) LT^{-2}, L and T

Q.3 Dimensions of resistance in an electrical circuit, in terms of mass M, length L, time T and current I, would be – **[AIPMT 2007]**

(A) ML^2T^{-2} (B) $ML^{-1}T^{-1}I^{-1}$
(C) $ML^2T^{-3}I^{-2}$ (D) $ML^2T^{-3}I^{-1}$

Q.4 Which two of the following five physical parameters have the same dimensions ? **[AIPMT 2008]**

(a) Energy density (b) Refractive index
(c) Dielectric constant (d) Young's modulus
(e) Magnetic field

(A) (a) and (e) (B) (b) and (d)
(C) (c) and (e) (D) (a) and (d)

Q.5 If the error in the measurement of radius of a sphere is 2 %, then the error in the determination of volume of the sphere will be – **[AIPMT 2008]**

(A) 2 % (B) 4 % (C) 6 % (D) 8 %

Q.6 If the dimensions of a physical quantity are given by $M^a L^b T^c$, then the physical quantity will be:

(A) Velocity if a = 1, b = 0, c = –1 **[AIPMT 2009]**
(B) Acceleration if a = 1, b = 1, c = –2
(C) Force if a = 0, b = –1, c = –2
(D) Pressure if a = 1, b = –1, c = –2

Q.7 The dimension of $\frac{1}{2}\varepsilon_0 E^2$, where ε_0 is permittivity of free space and E is electric field, is – **[AIPMT (PRE) 2010]**

(A) ML^2T^{-2} (B) $ML^{-1}T^{-2}$
(C) ML^2T^{-1} (D) MLT^{-1}

Q.8 The dimensions of $(\mu_0\varepsilon_0)^{-1/2}$ are – **[AIPMT (PRE) 2011, AIPMT (MAINS) 2012]**

(A) $[L^{-1/2}T^{1/2}]$ (B) $[L^{1/2}T^{-1/2}]$
(C) $[L^{-1}T]$ (D) $[LT^{-1}]$

Q.9 The density of material in CGS system of units is $4 g/cm^3$. In a system of units in which unit of lengths is 10 cm & unit of mass is 100 g, the value of density of material will be: **[AIPMT (MAINS) 2011]**

(A) 0.4 (B) 40
(C) 400 (D) 0.04

Q.10 The damping force on an oscillator is directly proportional to the velocity. The units of the constant of proportionality are **[AIPMT (PRE) 2012]**

(A) $kgms^{-1}$ (B) $kgms^{-2}$
(C) kgs^{-1} (D) kgs

Q.11 In an experiment four quantities a, b, c and d are measured with percentage error 1%, 2%, 3% and 4% respectively. Quantity P is calculated as follows $P = a^3b^2/cd$. % error in P is – **[NEET 2013]**

(A) 4% (B) 14%
(C) 10% (D) 7%

Q.12 If force (F), velocity (V) and time (T) are taken as fundamental units, then the dimensions of mass are **[AIPMT 2014]**

(A) $[F V T^{-1}]$ (B) $[F V T^{-2}]$
(C) $[F V^{-1} T^{-1}]$ (D) $[F V^{-1} T]$

Q.13 If energy (E), velocity (V) and time (T) are chosen as the fundamental quantities, the dimensional formula of surface tension will be: **[AIPMT 2015]**

(A) $[EV^{-1} T^{-2}]$ (B) $[EV^{-2}T^{-2}]$
(C) $[E^{-2}V^{-1}T^{-3}]$ (D) $[EV^{-2}T^{-1}]$

Q.14 In dimension of critical velocity v_c, of liquid following through a tube are expressed as $(\eta^x \rho^y r^z)$, where η, ρ and r are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of x, y and z are given by : **[RE-AIPMT 2015]**

(A) 1, 1, 1 (B) 1, –1, –1
(C) –1, –1, 1 (D) –1, –1, –1

Q.15 Planck's constant (h), speed of light in vacuum (c) and Newton's gravitational constant (G) are three fundamental constants. Which of the following combinations of these has the dimension of length? **[NEET 2016 PHASE 2]**

(A) $\frac{\sqrt{hG}}{c^{3/2}}$ (B) $\frac{\sqrt{hG}}{c^{5/2}}$ (C) $\sqrt{\frac{hc}{G}}$ (D) $\sqrt{\frac{Gc}{h^{3/2}}}$

Q.16 A physical quantity of the dimensions of length that can be formed out of c, G and $\frac{e^2}{4\pi\varepsilon_0}$ is [c is velocity of light, G is universal constant of gravitation and e is charge] **[NEET 2017]**

(A) $c^2\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$ (B) $\frac{1}{c^2}\left[\frac{e^2}{G4\pi\varepsilon_0}\right]^{1/2}$

(C) $\frac{1}{c}G\frac{e^2}{4\pi\varepsilon_0}$ (D) $\frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$

Q.17 A student measured the diameter of a small steel ball using a screw gauge of least count 0.001cm. The main scale reading is 5 mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of –0.004 cm, the correct diameter of the ball is **[NEET 2018]**

(A) 0.053 cm (B) 0.525 cm
(C) 0.521 cm (D) 0.529 cm

Q.18 The unit of thermal conductivity is : **[NEET 2019]**
(A) $J\,m\,K^{-1}$ (B) $J\,m^{-1}\,K^{-1}$
(C) $W\,m\,K^{-1}$ (D) $W\,m^{-1}\,K^{-1}$

Q.19 In an experiment, the percentage of error occurred in the measurement of physical quantities A, B, C and D are 1%, 2%, 3% and 4% respectively. Then the maximum percentage of error in the measurement X, where $X = \frac{A^2B^{1/2}}{C^{1/3}D^3}$, will be **[NEET 2019]**
(A) (3/13)% (B) 16%
(C) – 10% (D) 10%

ANSWER KEY

EXERCISE - 1

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	B	B	B	B	A	D	C	D	B	A	C	D	A	D	C	B	B	C	A	D	A	C	B	A	C
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
A	C	D	A	D	C	A	B	C	A	B	C	A	C	C	D	C	C	C	B	C	A	A	D	D	C

EXERCISE - 2

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
A	C	C	C	B	A	B	A	B	D	C	D	B	B	C	B	B	A	C	B	A	A	D	D	C	D
Q	26	27	28	29	30	31	32	33	34	35	36	37	38	39											
A	C	B	C	D	D	C	A	C	B	A	B	B	B	A											

EXERCISE - 3

Q	1	2	3	4	
A	3	5	3	3	

EXERCISE - 4

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
A	B	A	B	C	C	D	B	B	D	A	D	A	A	B	D	B	D	B	A	D	C	C	B

EXERCISE - 5

Q	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
A	B	D	C	D	C	D	B	D	B	C	B	D	B	B	A	D	D	D	B

Actual acc. $= \dfrac{2\times 2}{(4.2)^2} = 0.23$

Error in acc. = 9.77% of 0.23 = 0.02

Thus $A = 0.23 \pm 0.02\ \text{m/s}^2$.

(8) Here, $s = (13.8 \pm 0.2)$ m ; $t = (4.0 \pm 0.3)$ s

velocity, $v = \dfrac{s}{t} = \dfrac{13.8}{4.0} = 3.45\ \text{ms}^{-1} = 3.5\ \text{ms}^{-1}$ (rounding off to two significant figures)

$$\frac{\Delta v}{v} = \pm\left(\frac{\Delta s}{s} + \frac{\Delta t}{t}\right) = \pm\left(\frac{0.2}{13.8} + \frac{0.3}{4.0}\right) = \pm\frac{(0.8 + 4.14)}{13.8 \times 4.0}$$

$$\Rightarrow \frac{\Delta v}{v} = \pm\frac{4.94}{13.8 \times 4.0} = \pm 0.0895$$

$\Delta v = \pm 0.0895 \times v = \pm 0.0895 \times 3.45 = \pm 0.3087 = \pm 0.31$ (rounding off to two significant fig.)

Hence, $v = (3.5 \pm 0.31)\ \text{ms}^{-1}$

% age error in velocity $= \dfrac{\Delta v}{v} \times 100 = \pm 0.0895 \times 100$

$= \pm 8.95\ \% = \pm 9\%$

(9) Weight of stone in air $= (10.0 \pm 0.1)$ kg

Loss of weight in water $= (10.0 \pm 0.1) - (5.0 \pm 0.1)$

$= (5 \pm 0.2)$ kg

When two quantities are subtracted (or added), the absolute errors are added up.

Now, Specific gravity

$$= \frac{\text{Weight in air}}{\text{Loss of weight in water}} = \frac{(10.0 \pm 0.1)\ \text{kg}}{(5 \pm 0.2)\ \text{kg}}$$

$\therefore$ Maximum percentage error in specific gravity

$$= \frac{0.1}{10.0} \times 100 + \frac{0.2}{5.0} \times 100 = 1\% + 4\% = 5\%.$$

(10) There are 3 significant figures in the measured mass whereas there are only 2 significant figures in the measured volume. Hence the density should be expressed to only 2 significant figures.

$$\text{Density} = \frac{5.74}{1.2}\ \text{gcm}^{-3} = 4.8\ \text{g cm}^{-3}.$$

Units and Measurements

TRY IT YOURSELF-1

(1) **(f).** While the answer may not be entirely clear-cut, most physicists would agree that none of the above statements are true.

(2) **(1)** A scientific hypothesis must be verifiable (in other words, one must be able to devise a test to see if the hypothesis is correct). Choice 1, while incorrect (smaller particles than atoms have been detected), is testable. Choice 2 can never be verified because the statement says that the substance in question is undetectable.

(3) **(D).** The SI units of power are equal to the SI units of energy divided by the SI units of time, s. The SI units of energy are the product of the SI units of force, kg-m/s^2 , and the SI units of distance, m. Therefore the SI units of energy are kg-m^2/s^2. Hence the SI units of power are kg-m^2/s^3.

(4) **(C).** The dimensions of energy are equal to the dimensions of force times distance. The dimensions of force are [M] [L] $[T^{-2}]$ and the dimensions of distance are [L] . Therefore the dimensions of energy are $[M][L^2][T^{-2}]$.

(5) The units of force are Newtons, or kg m/s^2.

For momentum, we have mass times velocity, or kg m/s. Thus, we have dimensions for these as

$[F] = m\,\ell\,t^{-2}$

$[p] = m\,\ell\,t^{-1}$

(6) We have four quantities in this problem, M, L, g and the period T. The dimensions of these are

$[M] = m, [L] = \ell, [g] = \ell\,t^{-2}, [T] = t$

We can form a single dimensionless quantity,

$$D = \frac{gT^2}{L} \quad \text{which leads to } T \propto \sqrt{\frac{\ell}{g}}$$

(7) $U = [k]\,[m]^{\alpha}\,[h]^{\beta}\,[g]^{\gamma}$, where k is a dimensionless constant.

$\Rightarrow\ [ML^2T^{-2}]=[M^0L^0T^0]\,[ML^0T^0]^{\alpha}\,[M^0LT^0]^{\beta}\,[M^0LT^{-2}]^{\gamma}$

$\Rightarrow\ [ML^2T^{-2}] = [M^{\alpha}L^{\beta+\gamma}T^{-2\gamma}]$

Equating dimensions on both sides,

$\alpha = 1\ ;\ -2\gamma = -2 \Rightarrow \gamma = 1$

and $\beta + \gamma = 2 \Rightarrow \beta = 2 - \gamma = 1$

$\therefore\ U = kmgh$

The actual relationship is U = mgh.

(8) Consider, $[K] = [v]^{\alpha}\,[a]^{\beta}\,[\rho]^{\gamma}$

$\Rightarrow\ [ML^2T^{-2}]=[LT^{-1}]^{\alpha}\,[LT^{-2}]^{\beta}\,[ML^{-3}]^{\gamma}$

$\Rightarrow\ [ML^2T^{-2}] = [M^{\gamma}L^{\alpha+\beta-3\gamma}T^{-\alpha-2\beta}]$

Equating the dimensions of like quantities on both sides

$\gamma = 1, \alpha + \beta - 3\gamma = 2\ ; -\alpha - 2\beta = -2$

Solving these equation, we get

$\alpha = 8, \beta = -3, \gamma = 1$

Hence, $[K] = [v^8a^{-3}\rho^1]$

(9) As N is number of nuclei, therefore it is dimensionless.

Now, as we know all exponential terms are dimensionless.

$$\therefore\quad N = \frac{[\alpha]}{[\beta]} \Rightarrow [M^0L^0T^0] = \frac{[\alpha]}{[\beta]} \Rightarrow [\alpha] = [\beta]$$

$$\text{Now, } \left[-\frac{\alpha E}{t}\right] = [M^0L^0T^0]$$

$$\Rightarrow\quad [\alpha] = \frac{[t]}{[E]} = \left[\frac{T}{ML^2T^{-2}}\right] \Rightarrow [\alpha] = [M^{-1}L^{-2}T^3]$$

Hence, $[\alpha] = [\beta] = [M^{-1}L^{-2}T^3]$

(10) $[LT^2]$

TRY IT YOURSELF-2

(1) (A)

(2) (B)

(3) (A)

(4) (A)

(5) **(D).** Here, $\ell = (5.7 \pm 0.1)$ cm, $b = (3.4 \pm 0.2)$ cm

Area $A = \ell \times b = 5.7 \times 3.4 = 19.38\ cm^2 = 19.0\ cm^2$ (rounding off to two significant fig.)

$$\frac{\Delta A}{A} = \pm\left(\frac{\Delta\ell}{\ell} + \frac{\Delta b}{b}\right) = \pm\left(\frac{0.1}{5.7} + \frac{0.2}{3.4}\right) = \pm\left(\frac{0.34 + 1.14}{5.7 \times 3.4}\right)$$

$$\frac{\Delta A}{A} = \pm\frac{1.48}{19.38} \Rightarrow \Delta A$$

$$= \pm\frac{1.48}{19.38} \times A = \pm\frac{1.48}{19.38} \times 19.38 = \pm 1.48$$

$\Delta A = \pm 1.5$ (rounding off to two significant figures)

$\therefore$ Area = (19.0 ± 1.5) sq.cm.

(6) (A)

(7) We use capital letters for quantities, lower case for errors. Solve the equation for the result, a. $A = 2S/T^2$.

Its indeterminate error equation is $\dfrac{a}{A} = 2\dfrac{t}{T} + \dfrac{s}{S}$

% error in acc. = 2 × % error in time + % error in distance

$$= 2 \times \frac{0.2}{4.2} \times 100 + \frac{0.005}{2} \times 100\% = 9.77\%$$

CHAPTER-2 : UNITS AND MEASUREMENTS
EXERCISE-1

(1) (B). Rocket propulsion – Newton's laws of motion.

(2) (B). The laws of nature do not change with time. Space is homogeneous and there is no preferred location in the universe.

(3) (B). Force of friction and tension in a string are electromagnetic forces.

(4) (B).

Name of force	Relative strength
Gravitational force	10^{-39}
Weak nuclear force	10^{-13}
Electromagnetic force	10^{-2}
Strong nuclear force	1

(5) (A) A scientific hypothesis must be verifiable (in other words, one must be able to devise a test to see if the hypothesis is correct). Choice (i), while incorrect (smaller particles than atoms have been detected), is testable. Choice (ii) can never be verified because the statement says that the substance in question is undetectable.

(6) (D). A symmetry of the laws of nature with respect to translation in space gives rise to conservation of linear momentum. In the same way isotropy of space (no intrinsically preferred direction in space) underlies the law of conservation of angular momentum. The conservation laws of charge and other attributes of elementary particles can also be related to certain abstract symmetries. Symmetries of space and time and other abstract symmetries play a central role in modern theories of fundamental forces in nature.

(7) (C). $1\text{mm} = 10^{-3}\text{ m}$; $1\text{ Å} = 10^{-10}\text{ m}$
$1\text{ fm} = 10^{-15}\text{ m}$. Among the given units fermi is the smallest unit.

(8) (D). ct^2 must have same unit as that of S.
$c \to m/s^2$

(9) (B). Surface tension $= \dfrac{\text{Force}}{\text{Length}} = \text{Newton/m}$

(10) (A). Unit of 'a' and 'v' should be same.

(11) (C). Impulse = Force $\times$ time $= (\text{kg-m/s}^2) \times \text{s} = \text{kg-m/s}$

(12) (D). One light year $= 9.46 \times 10^{15}$ meter

(13) (A). By definition of parsec

$$1\text{ parsec} = \frac{1\text{ AU}}{1\text{ arc second}}$$

$$1° = 3600\text{ arc second};\ 1° = \frac{\pi}{180}\text{ rad}$$

$$\therefore\ 1\text{ arc second} = \frac{\pi}{3600 \times 180}\text{rad}$$

$$\therefore\ 1\text{ parsec} = \frac{3600 \times 180}{\pi}\text{AU}$$

$$= 206265\text{ AU} \approx 2 \times 10^5\text{ AU}$$

(14) (D). The SI units of power are equal to the SI units of energy divided by the SI units of time, s. The SI units of energy are the product of the SI units of force, kg-m/s^2 , and the SI units of distance, m. Therefore the SI units of energy are kg-m^2/s^2. Hence the SI units of power are kg-m^2/s^3.

(15) (C). Other units are based on standard properties of atoms which can be universally replicated SI standard of mass is a mass of a body kept in lab under standard conditions.

(16) (B). 1 dyne $= 10^{-5}$ newton, 1 cm $= 10^{-2}$ m,
70 dyne/cm $= 70 \times 10^{-5}/10^{-2}$ N/m
$= 7 \times 10^{-2}$ N/m.

(17) (B). kWh is a unit of energy

(18) (C). Latent Heat

$$L = \frac{Q}{m} = \frac{\text{Energy}}{\text{mass}} = \frac{[ML^2T^{-2}]}{[M]} = [L^2T^{-2}]$$

(19) (A). As $x = at^2 + b$ therefore
$[a] = [LT^{-2}]$ and $[b] = [L]$
$\therefore$ $[ab] = [L^2T^{-2}] = [v^2]$

(20) (D). Quantities of same dimension are added.
Dimension of A $\to$ T
Dimension of B $\to$ LT
Dimension of AB $\to$ LT^2

(21) (A). Physical quantities having different dimensions cannot be added or subtracted.
As P, Q and R physical quantities having different dimensions, therefore they can neither be added nor be subtracted. Thus, (A) can never a meaningful quantity.

(22) (C). The dimensions of energy are equal to the dimensions of force times distance. The dimensions of force are [M] [L] [T^{-2}] and the dimensions of distance are [L]. Therefore the dimensions of energy are [M][L^2][T^{-2}].

(23) (B). Let force be $F = A^a v^b \rho^c$;

$$MLT^{-2} = [L^2]^a[LT^{-1}]^b[ML^{-3}]^c$$

$a = 1, b = 2, c = 1$; $F = Av^2\rho$

(24) (A). $$\frac{[ML^2T^{-2}][ML^2\,T^{-1}]^2}{[M^5][M^{-1}L^3T^{-2}]^2} = \frac{M^3\,L^6\,T^{-4}}{M^3\,L^6\,T^{-4}} = [M^0L^0T^0]$$

(25) (C). X has dimensions

$$MLT^{-2}\ \frac{M}{L^3} = M^2L^{-2}T^{-2}$$

(26) (C). Both numerically and dimensionally correct

(27) (D). $(\omega t + \phi) \to$ angle . Hence dimensionless.

(28) (A). The 4.9 cm measurement is more accurate because it is closer to the true value.

(29) (D). A wall clock can measure time correctly upto one second. A stop watch can measure time correctly upto a fraction of a second. A digital watch can measure time upto a fraction of seocnd.

An atomic clock can measure time most precisely as its precision is 1s in 10^3 s.

(30) (C). As $X = a^2b^3c^{5/2}d^{-2}$

The percentage error in X is

$$\frac{\Delta X}{X}\times 100 = \left[2\left(\frac{\Delta a}{a}\right)+3\left(\frac{\Delta b}{b}\right)+\frac{5}{2}\left(\frac{\Delta c}{c}\right)+2\left(\frac{\Delta d}{d}\right)\right]\times 100$$

$$= 2\times 1\% + 3\times 2\% + \frac{5}{2}\times 2\% + 2\times 4\% = 21\%$$

(31) (A). A mass spectrograph is used for measuring the mass of atoms and molecules.

(32) (B). Initial zero after the decimal point is not significant.

(33) (C). Screw gauge has minimum least count of 0.001 cm. Hence, it is most precise instrument.

(34) (A). All measurements are correct upto two places of decimal. However, the absolute error in (a) is 0.01 mm which is least of all the four. So it is most precise.

(35) (B). Given mass of the sun (M) = 2.0×10^{30} kg Radius of the Sun (R) = 7.0×10^8 m

$$\text{Density of the sun} = \frac{\text{Mass of the sun (M)}}{\text{Volume of the sun (V)}}$$

$$\rho = \frac{M}{\frac{4}{3}\pi R^3} = \frac{3}{4}\frac{M}{\pi R^3} = \frac{3\times 2.0\times 10^{30}}{4\times 3.14\times(7.0\times 10^8)^3}$$

$$= \frac{3\times 10^{30}}{6.28\times 343\times 10^{24}} = 1.392\times 10^3$$

$\approx 1.4\times 10^3\ kg/m^3$

(36) (C). Radius of the sphere, r = 1.41 cm.

(3 significant figures)

Volume of the sphere,

$$V = \frac{4}{3}\pi r^3 = \frac{4}{3}\times 3.14\times(1.41)^3 = 11.736\ cm^3$$

Rounded off upto 3 significant figures= 11.7 cm^3

(37) (A). One atomic mass unit is the 1/12 of the mass of a $_6C^{12}$ atom. Mass of one mole of $_6C^{12}$ atom = 12g.

Number of atoms in one mole

= Avogadro's number = 6.023×10^{23}

$$\text{Mass of one } _6C^{12} \text{ atom} = \frac{12}{6.023\times 10^{23}}\ g$$

$$1\ amu = \frac{1}{12}\times \text{mass of one } _6C^{12} \text{ atom}$$

$$1\ amu = \left(\frac{1}{12}\times\frac{12}{6.023\times 10^{23}}\right) g$$

$= 1.67\times 10^{-27}$ kg $[1g = 10^{-3}\ kg]$

(38) (C).

```
   436.32
 + 227.2
   0.301
 -------
  663.821
```

Since the least precise measurement 227.2 is correct to only one decimal place. Therefore, the final result should be rounded off to 663.8.

(39) (C). $2r = 10\times 1 + 0\times LC$

$2r = 10mm = 1$ cm. So $r = 0.5$ cm.

(40) (D). $\text{Pitch} = \frac{2mm}{8} = 0.25mm$

$$L.C. = \frac{0.25mm}{250} = 0.001mm$$

Observed diameter = MSR + (Coinciding division× L.C.)

$= (15\times 0.25\ mm) + (100\times 0.001\ mm)$

$= 3.75mm + 0.100mm = 3.850\ mm$

(41) (C) **(42)** (C) **(43)** (C)

(44) (B). $E = KF^aA^bT^c$

$[ML^2T^{-2}] = [MLT^{-2}]^a\ [LT^{-2}]^b[T]^c$

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

$\therefore$ $a = 1,\ a + b = 2 \Rightarrow b = 1$

and $-2a - 2b + c = -2 \Rightarrow c = 2$

$\therefore$ $E = KFAT^2$.

(45) (C). $\frac{eV}{T} = \frac{\text{energy}}{\text{temperature}} = K$

Boltzman constant

(46) (A). Absolute error same for both, relative error greater for M_A and lesser for M_B.

(47) (A). Each measurement has 3 significant figures.

$\therefore$ Length ℓ can be written as

$\ell = 16.2\pm 0.1\ cm = 16.2\ cm \pm 0.6\%$

Similarly, the breadth b can be written as

$b = 10.1\pm 0.1\ cm = 10.1\ cm\pm 1\%$

Area of the sheet,

$A = \ell\times b \quad = 163.62\ cm^2 \pm 1.6\%$

$= 163.62 \pm 2.6\ cm^2$

Area will have only 3 significant figures and error will have only one significant figure.

Rounding off, we get $A = 164\pm 3\ cm^2$.

(48) (D). Weight of stone in air = (10.0 ± 0.1) kg

Loss of weight in water

$= (10.0\pm 0.1) - (5.0\pm 0.1) = (5\pm 0.2)$ kg

When two quantities are subtracted (or added), the absolute errors are added up.

Now, Specific gravity

$$= \frac{\text{Weight in air}}{\text{Loss of weight in water}} = \frac{(10.0\pm 0.1)\ kg}{(5\pm 0.2)\ kg}$$

$\therefore$ Maximum % error in specific gravity

$$= \frac{0.1}{10.0}\times 100 + \frac{0.2}{5.0}\times 100 = 1\% + 4\% = 5\%.$$

(49) **(D).** Here, A = 1.0 m ± 0.2 m, B = 2.0 m ± 0.2m
AB = (1.0 m) (2.0 m) = 2.0 m^2

$\sqrt{AB} = \sqrt{2.0}m = 1.414$ m

Rounding off to two significant figures, we get

$\sqrt{AB} = 1.4$ m

$$\frac{\Delta\sqrt{AB}}{\sqrt{AB}} = \frac{1}{2}\left(\frac{\Delta A}{A}+\frac{\Delta B}{B}\right) = \frac{1}{2}\left(\frac{0.2}{1.0}+\frac{0.2}{2.0}\right) = \frac{0.3}{2}$$

$$\Delta\sqrt{AB} = \frac{0.3}{2}\times\sqrt{AB} = \frac{0.3}{2}\times 1.414 = 0.212\text{ m}$$

Rounding off to one Significant figure, we get $\Delta\sqrt{AB} = 0.2$ m . The correct value for $\sqrt{AB}$ is 1.4 m ± 0.2m.

(50) **(C).**

EXERCISE-2

(1) **(C).** $F = \frac{Gm_1m_2}{d^2}$; $G = \frac{Fd^2}{m_1m_2} = Nm^2/kg^2$

(2) **(C).** Stefan's law is $E = \sigma(T^4) \Rightarrow \sigma = \frac{E}{T^4}$

where, $E = \frac{\text{Energy}}{\text{Area}\times\text{Time}} = \frac{\text{Watt}}{m^2}$

$$\sigma = \frac{\text{Watt-m}^{-2}}{K^4} = \text{Watt} - m^{-2}K^{-4}$$

(3) **(C).** Curie = disintegration/second

(4) **(B) .** Units of a and PV^2 are same and equal to dyne × cm^4.

(5) **(A).**

(6) **(B).**

(7) **(A).** Here, A = 2.5 ms^{-1} ± 0.5 ms^{-1}
B = 0.10 s ± 0.01 s
AB = (2.5 ms^{-1}) (0.10 s) = 0.25 m

$$\frac{\Delta AB}{AB} = \left(\frac{\Delta A}{A}+\frac{\Delta B}{B}\right) = \left(\frac{0.5}{2.5}+\frac{0.01}{0.10}\right)$$
$= 0.3$

ΔAB = 0.3 × 0.25 m = 0.075 m
= 0.08 m
(Rounded off to two significant figures
The value of AB is (0.25 ± 0.08) m.

(8) **(B).** The final result should be 3 significant figures.

(9) **(D).** In 2.745, the digit to be rounded off (i.e., 4) is even, hence it should be left unchanged and in 2.735, the digit to be rounded off (i.e., 3) is odd, hence it should be increased by 1, i.e., changed to 4.

(10) **(C).** $R = \frac{V}{I} = \frac{W}{QI} = \frac{ML^2T^{-2}}{A^2T} = ML^2T^{-3}A^{-2}$

$\frac{h}{e^2} = ML^2T^{-3}A^{-2}$

(11) **(D).** CV^2 = Energy
∴ The dimentional formula is ML^2T^{-2}

(12) **(B).** Frequency = 1/T ; Force = MLT^{-2}

(13) **(B).** $[V] = M^1L^2T^{-3}A^{-1}$ & $[RC] = M^0L^0T^1$

(14) **(C).** $\frac{\Delta Q}{Q} = 3\frac{\Delta x}{x} + 2\frac{\Delta y}{y} + \frac{\Delta z}{z}$
$= 3\times1 + 2\times2 + 4 = 11\%$

(15) **(B).** $F = \frac{GM_1m_1}{r^2} \Rightarrow G = \frac{Fr^2}{M_1m_2}$

∴ Dimension of $G = \frac{[MLT^{-2}][L^2]}{[M][M]} = M^{-1}L^3T^{-2}$

(16) **(B).** The units of force are Newtons, or kg m/s^2. For momentum, we have mass times velocity, or kg m/s. Thus, we have dimensions for these as $[F] = m\,\ell\,t^{-2}$; $[p] = m\,\ell\,t^{-1}$

(17) **(A).** $T \propto M^aL^bg^c$
Solving dimensionally, a = 0, b = 1/2, c = –1/2

(18) **(C).** Consider, $[K] = [v]^\alpha [a]^\beta [\rho]^\gamma$
$\Rightarrow [ML^2T^{-2}] = [LT^{-1}]^\alpha [LT^{-2}]^\beta [ML^{-3}]^\gamma$
$\Rightarrow [ML^2T^{-2}] = [M^\gamma L^{\alpha+\beta-3\gamma} T^{-\alpha-2\beta}]$
Equating the dimensions of like quantities on both sides $\gamma = 1, \alpha+\beta-3\gamma = 2; -\alpha-2\beta = -2$
Solving these equation, we get α = 8, β = –3, γ = 1
Hence, $[K] = [v^8a^{-3}\rho^1]$

(19) **(B).** As N is number of nuclei, therefore it is dimensionless.
Now, as we know all exponential terms are dimensionless.

∴ $N = \frac{[\alpha]}{[\beta]} \Rightarrow [M^0L^0T^0] = \frac{[\alpha]}{[\beta]} \Rightarrow [\alpha] = [\beta]$

Now, $\left[-\frac{\alpha E}{t}\right] = [M^0L^0T^0]$

$\Rightarrow [\alpha] = \frac{[t]}{[E]} = \left[\frac{T}{ML^2T^{-2}}\right] \Rightarrow [\alpha] = [M^{-1}L^{-2}T^3]$

Hence, $[\alpha] = [\beta] = [M^{-1}L^{-2}T^3]$

(20) **(A).** Let $F \propto P^xV^yT^z$
By substituting the following dimensions :
$[P] = [ML^{-1}T^{-2}]$; $[V] = [LT^{-1}], [T] = [T]$
and comparing the dimension of both sides
x = 1, y = 2, z = 2, so $F = PV^2T^2$

(21) **(A).** For maximum error always add fractional error.

(22) **(D).** Here, ℓ = (5.7 ± 0.1) cm,
b = (3.4 ± 0.2) cm
Area, A = ℓ × b = 5.7 × 3.4 = 19.38 cm^2
= 19.0 cm^2
(rounding off to two significant figures)

$$\frac{\Delta A}{A} = \pm\left(\frac{\Delta\ell}{\ell}+\frac{\Delta b}{b}\right) = \pm\left(\frac{0.1}{5.7}+\frac{0.2}{3.4}\right) = \pm\left(\frac{0.34+1.14}{5.7\times3.4}\right)$$

$$\frac{\Delta A}{A} = \pm\frac{1.48}{19.38} \Rightarrow \Delta A = \pm\frac{1.48}{19.38}\times A$$

$$= \pm\frac{1.48}{19.38}\times 19.38 = \pm 1.48$$

$\Delta A = \pm 1.5$

(rounding off to two significant figures)

$\therefore$ Area = (19.0 ± 1.5) sq. cm.

(23) (D). We use capital letters for quantities, lower case for errors. Solve the equation for the result,

a. $A = 2S/T^2$

Its indeterminate error equation is

$$\frac{a}{A} = 2\frac{t}{T} + \frac{s}{S}$$

% error in acceleration

= 2 × % error in time + % error in distance

$$= 2\times\frac{0.2}{4.2}\times 100 + \frac{0.005}{2}\times 100\% = 9.77\%$$

Actual acceleration $= \frac{2\times 2}{(4.2)^2} = 0.23$

Error in acceleration. = 9.77% of 0.23

= 0.02

Thus $A = 0.23 \pm 0.02\ m/s^2$.

(24) (C). There are 3 significant figures in the measured mass whereas there are only 2 significant figures in the measured volume. Hence the density should be expressed to only 2 significant figures.

Density $= \frac{5.74}{1.2}\,gcm^{-3} = 4.8\ g\ cm^{-3}$.

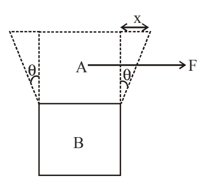
(25) (D). Method 1 : Check the options dimensionally. Only option (D) satisfy dimension of T.

Method 2 : If the block A gets deformed with a shearing angle $\theta = x/L$ which is small,

The shearing force

= η × shear angle × area

$= \eta\theta A = (\eta x/L)L^2 = \eta xL$.



Hence $M\frac{d^2x}{dt} = -\eta xL$

or $\frac{d^2x}{dt} = -\left(\frac{\eta L}{M}\right)x = -\omega^2 x$

Now, $T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{M}{\eta L}}$

(26) (C). Volume flow rate $\propto P^x R^Y \ell^Z \rho^\alpha \eta^\beta$

$$\frac{L^3}{T} = [M^x L^{-x} T^{-2x}][L^y][L^z]$$

$$[M^\alpha L^{-3\alpha}][M^\beta L^{-\beta} T^{-\beta}]$$

$x + \alpha + \beta = 0$; $2x + \beta = 1$

$-x + y + z - 3\alpha - \beta = 3$

Solving above equations with the help of options

$x = 1, y = 4, z = -1, \alpha = 0, \beta = -1$

(27) (B). 1 sec* = 5 sec, 1kg* = 20 kg, 1m* = 10m

1 watt = 1 kg m^2 sec^{-3}

$$= \frac{1}{20}kg*\left(\frac{1}{10}m*\right)^2\left(\frac{1}{5}sec*\right)^{-3}$$

$$= \frac{1}{20}\times\frac{1}{100}\times 125\ kg*m*^2\ sec*^{-3} = \frac{1}{16}watt*$$

(28) (C). Force has dimension $[MLT^{-2}]$ while impulse has dimension $[MLT^{-1}]$, both have defferent dimension.

(29) (D). We know that $E = h\nu$

$$h = \frac{E}{\nu} = \frac{[ML^2T^{-2}]}{[T^{-1}]} = [ML^2T^{-1}]$$

Angular momentum $= I\omega = [ML^2][T^{-1}]$

$= [ML^2T^{-1}]$

(30) (D). $\varepsilon_0 = \frac{q^2}{(r^2)\,4\pi F}$

$\Rightarrow$ Unit of ε_0 is $(coulomb)^2/Newton\text{-}metre^2$

(31) (C). $n_2 = n_1\left(\frac{M_1}{M_2}\right)^1\left(\frac{L_1}{L_2}\right)^1\left(\frac{T}{T_2}\right)^{-2}$

$$= 100\left(\frac{gm}{kg}\right)^1\left(\frac{cm}{m}\right)^1\left(\frac{sec}{min}\right)^{-2}$$

$$= 100\left(\frac{gm}{10^3 gm}\right)^1\left(\frac{cm}{10^2 cm}\right)^1\left(\frac{sec}{60\,sec}\right)^{-2}$$

$$n_2 = \frac{3600}{10^3} = 3.6$$

(32) (A). [L/R] is a time constant so its unit is second.

(33) (C). Let $v^x = kg^y \lambda^z \rho^\delta$.

Now by substituting the dimensions of each quantities and equating the powers of M, L and T we get $\delta = 0$ and

$x = 2, y = 1, z = 1$.

(34) (B). $f = \frac{1}{2\pi\sqrt{LC}} \Rightarrow LC = \frac{1}{f^2} = [M^0L^0T^2]$

(35) (A). By substituting the dimension of each quantity we get $T = [ML^{-1}T^{-2}]^a[L^{-3}M]^b[MT^{-2}]^c$

By solving we get $a = -3/2$, $b = 1/2$ and $c = 1$

(36) (B). $C = \frac{1}{\sqrt{\mu_0\varepsilon_0}} \Rightarrow \mu_0\varepsilon_0 = \left(\frac{1}{C^2}\right)$

(where C = velocity of light)

$\therefore$ $[\mu_0\varepsilon_0] = L^{-2}T^2$

(37) **(B).** By substituting the dimension of given quantities

$[ML^{-1}T^{-2}]^x[MT^{-3}]^y[LT^{-1}]^z = [MLT]^0$

By comparing the power of M, L, T in both sides

$x + y = 0$ ....(i)

$-x + z = 0$ .....(ii)

$-2x - 3y - z = 0$ ...(iii)

The only values of x, y, z satisfying (i), (ii) and (iii) corresponds to (B).

(38) **(B).** $L \propto v^x A^y F^z \Rightarrow L = kv^x A^y F^z$

Putting the dimensions in the above relation

$[ML^2T^{-1}] = k[LT^{-1}]^x[LT^{-2}]^y[MLT^{-2}]^z$

$\Rightarrow [ML^2T^{-1}] = k[M^zL^{x+y+z}T^{-x-2y-2z}]$

Comparing the powers of M, L and T

$z = 1$ ...(i)

$x + y + z = 2$ ...(ii)

$-x - 2y - 2z = -1$ ...(iii)

On solving (i), (ii) and (iii)

$x = 3y, y = -2, z = 1$

So dimension of L in terms of v, A and f

$[L] = [Fv^3A^{-2}]$

(39) **(A).** Let $T \propto S^x r^y \rho^z$

By substituting the dimension of [T] = [T]

$[S] = [MT^{-2}], [r] = [L], [\rho] = [ML^{-3}]$

and by comparing the power of both the sides

$x = -1/2, y = 3/2, z = 1/2$

So, $T \propto \sqrt{\rho r^3 / S} \Rightarrow T = k\sqrt{\frac{\rho r^3}{S}}$

EXERCISE-3

(1) **3.** $d = \rho^a s^b f^c$

$M^0L^1T^0 = M^aL^{-3a} \times M^bT^{-3b}T^{-c}$

$= M^{a+b}L^{-3a}T^{-3b-c}$

$a + b = 0, -3a = 1$

$\Rightarrow a = -1/3, b = 1/3$

$\therefore n = 3$

(2) **5.** In new system, 1g* = 10g, 1cm* = 5cm.

$I = 6 \times 100 \times g^* (20\ cm^*)^2 = 6 \times 100 \times 400\ g \times cm^{*2}$

$= 2.4 \times 10^5\ g^*\ cm^{*2}$

(3) **3.** $\frac{\Delta H}{H} = \frac{2\Delta I}{I} + \frac{\Delta R}{R} + \frac{\Delta t}{t}$

$\Rightarrow \frac{\Delta H}{H} \times 100 = 2\ (2\%) + 1\% + 1\%$ $\Rightarrow$

$\frac{\Delta H}{H} \times 100 = 6\%$

(4) **3.** $V = \pi r^2 \ell$

$\frac{\Delta V}{V}\% = 2\frac{\Delta r}{r}\% + \frac{\Delta \ell}{\ell}\%$

$= 2 \times \frac{0.01}{2} \times 100\% + \frac{0.1}{5} \times 100\% = 1\% + 2\% = 3\%$

EXERCISE-4

(1) **(B).** Torque $[\tau] = [M^1L^2T^{-2}]$

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

(2) **(A).** Momentum = mv

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

Plank constant $P = \frac{h}{\lambda}$

$h = P\lambda$

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

(3) **(B).** $\frac{1}{\sqrt{\mu_0\varepsilon_0}} = c$; $\frac{1}{\mu_0\varepsilon_0} = c^2$

(4) **(C).** $F = 6\pi\eta rv$

$\eta = \frac{F}{6\pi rv} = \frac{M^1L^1T^{-2}}{[L^1][L^1T^{-1}]} = [M^1L^{-1}T^{-1}]$

(5) **(C).** Moment of inertia $[I] = [M^1L^2T^0]$

Moment of force $[\tau] = [M^1L^2T^{-2}]$

(6) **(D).** $\frac{ML^2}{Q^2} = \frac{M^1L^2}{A^2T^2} = [M^1L^2A^{-2}T^{-2}]$

Henry (H) $\phi = LI$; $L = \frac{\phi}{I}$

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

(7) **(B).** Force $F = qvB$; $B = \frac{F}{qv} = \frac{M^1L^1T^{-2}}{(C)\ (L^1T^{-1})}$

(8) **(B).** $F = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{R^2}$; $\epsilon_0 = \frac{q_1q_2}{4\pi FR^2}$

Hence, $\epsilon_0 = \frac{C^2}{N.m^2} = \frac{[AT]^2}{MLT^{-2}.L^2} = [M^{-1}L^{-3}T^4A^2]$

(9) **(D).** L.C. of vernier calliper (1/10) mm = 0.1 mm = 0.01 cm

(10) **(A).** $g = 4\pi^2 \cdot \frac{\ell}{T^2} \Rightarrow \frac{\Delta g}{g} \times 100 = \frac{\Delta \ell}{\ell} \times 100 + 2\frac{\Delta T}{T} \times 100$

$= \frac{\Delta \ell}{\ell} \times 100 + 2\frac{\Delta t}{t} \times 100 = \frac{0.1}{20.0} \times 100 + 2 \times \frac{1}{90} \times 100$

$= \frac{100}{200} + \frac{200}{90} = \frac{1}{2} + \frac{20}{9} \cong 3\%$

(11) **(D).** $\bar{X} = \frac{\Sigma X_i}{N} = 92$

σ^2 (Standard dev.) $= \dfrac{\Sigma (X_i - \bar{X})^2}{N} = \dfrac{1+4+9+0}{4}$

$\Rightarrow \sigma = 1.8$. But since LC of clock is 1s, rounding off to the correct sign : Time : $92 \pm 2s$

(12) **(A).** $LC = \dfrac{0.5}{50} = 0.01$ mm

Zero error $= -0.5 + 45 \times 0.01 = -0.05$mm
Measured reading $= 0.5 + 25 \times 0.01 = 0.75$ mm
Actual reading = Measured reading – Z.E.
$= 0.75\text{mm} - (0.05) = 0.80$ mm

(13) **(A).** $\rho = \dfrac{M}{V} = \dfrac{M}{L^3}$; $\dfrac{\Delta\rho}{\rho} = \dfrac{\Delta M}{M} + 3\dfrac{\Delta L}{L}$

$\therefore$ Maximum % error in density $= 1.5\% + 3\,(1\%) = 4.5\%$

(14) **(B).** $LC = \dfrac{\text{Pitch}}{\text{No. of division}}$; $LC = 0.5 \times 10^{-2}$ mm

+ve error $= 3 \times 0.5 \times 10^{-2}$ mm $= 1.5 \times 10^{-2}$ mm $= 0.015$ mm
Reading = MSR + CSR – (+ve error)
$= 5.5$ mm $+ (48 \times 0.5 \times 10^{-2}) - 0.015$
$= 5.5 + 0.24 - 0.015 = 5.725$ mm

(15) **(D).** $F = \dfrac{GM^2}{R^2} \Rightarrow G = [M^{-1}L^3T^{-2}]$

$E = h\nu \Rightarrow h = [ML^2T^{-1}]$; $C = [LT^{-1}]$
$t \propto G^x h^y C^z$
$[T] = [M^{-1}L^3T^{-2}]^x [ML^2T^{-1}]^y [LT^{-1}]^z$
$[M^0L^0T^1] = [M^{-x+y} L^{3x+2y+z} T^{-2x-y-z}]$
On comparing the powers of M, L, T
$-x + y = 0 \Rightarrow x = y$
$3x + 2y + z = 0 \Rightarrow 5x + z = 0$ ....(i)
$-2x - y - z = 1 \Rightarrow 3x + z = -1$ ...(ii)
On solving (i) & (ii) $x = y = 1/2$, $z = -5/2$

$t \propto \sqrt{\dfrac{Gh}{C^5}}$

(16) **(B).** Dimension of $\sqrt{\dfrac{\varepsilon_0}{\mu_0}}$

$[\varepsilon_0] = [M^{-1}L^{-3}T^4A^2]$
$[\mu_0] = [MLT^{-2}A^{-2}]$

Dimensions of $\sqrt{\dfrac{\varepsilon_0}{\mu_0}} = \left[\dfrac{M^{-1}L^{-3}T^4A^2}{MLT^{-2}A^{-2}}\right]^{1/2}$

$= [M^{-2}L^{-4}T^6A^4]^{1/2} = [M^{-1}L^{-2}T^3A^2]$

(17) **(D).** $T = \dfrac{30\text{sec}}{20}$; $\Delta T = \dfrac{1}{20}$sec

$L = 55$ cm, $\Delta L = 1$ mm $= 0.1$ cm ; $g = \dfrac{4\pi^2 L}{T^2}$

Percentage error in g is

$\dfrac{\Delta g}{g} \times 100\% = \left(\dfrac{\Delta L}{L} + \dfrac{2\Delta T}{T}\right) \times 100\%$

$= \left(\dfrac{0.1}{55} + \dfrac{2\,(1/20)}{30/20}\right) \times 100\% = 6.8\%$

(18) **(B).** $p = k\, s^a I^b h^c$, where k is dimensionless constant
$MLT^{-1} = (MT^{-2})^a (ML^2)^b (ML^2T^{-1})^c$
$a + b + c = 1$
$2b + 2c = 1$
$-2a - c = -1$
$a = 1/2, b = 1/2, c = 0$; $s^{1/2}I^{1/2}h^0$

(19) **(A).** Energy density in magnetic field $= \dfrac{B^2}{2\mu_0}$

$= \dfrac{\text{Force} \times \text{displacement}}{(\text{displacement})^3} = \dfrac{MLT^{-2}L}{L^3} = ML^{-1}T^{-2}$

(20) **(D).** $v_0 = h^x c^y G^z A^w$

$\dfrac{ML^2T^{-2}}{AT} = (ML^2T^{-1})^x (LT^{-1})^y (M^{-1}L^3T^{-2})^z A^w$

$\Rightarrow$ $w = -1$
$(x - z = 1)$
$2x + y + 3x = 2$
$-x - y - 2z = -3$

$2x = 0$
$x = 0$
$z = -1$
$2 \times 0 + y + 3x - 1 = 2$; $y = 5$
$\Rightarrow$ $v_0 = h^0c^5G^{-1}A^{-1}$

(21) **(C).** $T = 2\pi\sqrt{\dfrac{\ell}{g}}$; $g = \dfrac{4\pi^2\ell}{T^2}$

$\dfrac{\Delta g}{g} = \dfrac{\Delta\ell}{\ell} + \dfrac{2\Delta T}{T} = \dfrac{0.1}{25} + \dfrac{2 \times 1}{50} = 4.4\%$

(22) **(C).** $[h] = M^1L^2T^{-1}$
$[C] = L^1T^{-1}$
$[G] = M^{-1}L^3T^{-2}$

$[f] = \sqrt{\dfrac{M^1L^2T^{-1} \times L^5T^{-5}}{M^{-1}L^3T^{-2}}} = M^1L^2T^{-2}$

(23) **(B).** Given on six rotation, reading of main scale changes by 3mm.

$\therefore$ 1 rotation corresponds to $\dfrac{1}{2}$ mm

Also no. of division on circular scale = 50.
$\therefore$ Least count of the screw gauge will be

$\dfrac{0.5}{50}$ mm $= 0.001$ cm.

EXERCISE-5

(1) **(B).** $\dfrac{\text{Planck's constant}}{\text{Moment of inertia}} = \dfrac{\frac{2\pi I\omega}{n}}{I}$ $\left[\text{As } \dfrac{nh}{2\pi} = I\omega\right]$

$= \dfrac{2\pi I\,(2\pi f)}{nI} = \left(\dfrac{4\pi^2}{n} f\right) = [T^{-1}]$

(2) **(D).** Dimension of at = dimension of velocity

$a\,.\,T = LT^{-1} \Rightarrow a = L\,T^{-2}$

Dimension of C = dimension of t (two physical quanity of same dimension can only be added).

So, dimension of C = T

$$\text{Dimension of } \frac{t}{b+c} = \text{Dimension of V}$$

$$\frac{b}{T+T} = LT^{-1} \Rightarrow b.T^{-1} = LT^{-1}$$

$\Rightarrow$ b = L. So, answer is LT^{-2}, L & T

(3) **(C).** Dimension of Resistance,

$$R = \frac{[V]}{[I]} = \frac{[ML^{-2}T^{-3}I^{-1}]}{[I]} = [ML^{2}T^{-3}I^{-2}]$$

(4) **(D).** $[\text{Energy density}] = \dfrac{[W]}{L^3} = \dfrac{[F].[L]}{[L^3][L]} = \dfrac{F}{[L^3]} = [P]$

(5) **(C).** $V \propto R^3\,;\ \dfrac{\Delta V}{V} = \dfrac{3\Delta R}{R}$

(6) **(D).** $\text{Pressure} = \dfrac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}$

$\Rightarrow$ a = 1, b = –1, c = –2

(7) **(B).** Energy density of an electric field E is $u_E = \dfrac{1}{2}\varepsilon_0 E^2$

where ε_0 permittivity of free space

$$\frac{\text{Energy}}{\text{Volume}} = \frac{ML^2T^{-2}}{L^3} = ML^{-1}T^{-2}$$

The dimension of $\dfrac{1}{2}\varepsilon_0 E^2$ is $ML^{-1}T^{-2}$.

(8) **(D).** Given expression is that of speed of light.

(9) **(B).** In CGS, $d = 4\ g/cm^3$

If unit of mass is 100 g and unit of distance is 10 cm.

$$\text{Density} = \frac{4\left(\frac{100g}{100}\right)}{\left(\frac{10}{10}cm\right)^3} = \frac{\left(\frac{4}{100}\right)}{\left(\frac{1}{10}\right)^3}\frac{(100g)}{(10cm)^3} = 40\ \text{unit}$$

(10) **(C).** $F \propto v \Rightarrow F = kV;\ k = \dfrac{F}{v} \Rightarrow [k] = \dfrac{[kgms^{-2}]}{[ms^{-1}]} = kg\,s^{-1}$

(11) **(B).** $P = \dfrac{a^3b^2}{cd} \Rightarrow \dfrac{\Delta P}{P} = \pm\left(3\dfrac{\Delta a}{a} + 2\dfrac{\Delta b}{b} + \dfrac{\Delta c}{c} + \dfrac{\Delta d}{d}\right)$

$= \pm(3 \times 1 + 2 \times 2 + 3 + 4) = \pm 14\%$

(12) **(D).** $F = [M\,V\,T^{-1}] \Rightarrow M = [F\,V^{-1}\,T]$

(13) **(B).** Let surface tension, $\sigma = E^a\,V^b\,T^c$

Equating the dimension of LHS and RHS

$$\frac{M^1L^1T^{-2}}{L} = (M^1L^2T^{-2})^a\left(\frac{L}{T}\right)^b (T)^c$$

$$M^1L^0T^{-2} = M^aL^{2a+b}\,T^{-2a-b+c}$$

$\Rightarrow$ a = 1, 2a + b = 0, .2a . b + c = .2

$\Rightarrow$ a = 1, b = –2 c = –2

(14) **(B).** $v_c \propto [\eta^x\rho^y r^z]$

$[L^1T^{-1}] \propto [M^1\,L^{-1}\,T^{-1}]^x\,[M^1\,L^{-3}\,]^y\,[L^1]^z$

$[L^1T^{-1}] \propto [M^{x+y}]\,[L^{-x-3y+z}]\,[T^{-x}]$

Taking comparision on both size

x + y = 0, – x – 3y + z = 1, –x = –1

$\Rightarrow$ x = 1, y = –1, z = –1

(15) **(A).** $L \propto h^xc^yG^z$.

$[L]^1 = [M^1L^2T^{-1}]^x\,[LT^{-1}]^y\,[M^{-1}L^3T^{-2}]^z$

Solving, x = 1/2, y = –3/2, z = 1/2

$$L = \frac{\sqrt{hG}}{c^{3/2}}$$

(16) **(D).** $[L] = [c]^a\,[G]^b\left[\dfrac{e^2}{4\pi\varepsilon_0}\right]^c$

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

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

a + 3b + 3c =1 ; – b + c = 0 ; a + 2b + 2c = 0

On solving, a = –2 , b = 1/2, c = 1/2

$$\therefore\ L = \frac{1}{c^2}\left[G\frac{e^2}{4\pi\varepsilon_0}\right]^{1/2}$$

(17) **(D).** Diameter of the ball

= MSR + CSR × (Least count)– Zero error

= 0.5 cm + 25 × 0.001 – (–0.004)

= 0.5 + 0.025 + 0.004 = 0.529 cm

(18) **(D).** The heat current related to difference of temperature across the length ℓ of a conductor of area A is

$$\frac{dH}{dt} = \frac{KA}{\ell}\Delta T$$

(K = coefficient of thermal conductivity)

$\therefore\ K = \dfrac{\ell\,dH}{A\,dt\,\Delta T}$. Unit of $K = Wm^{-1}\,K^{-1}$

(19) **(B).** Given, $X = \dfrac{A^2B^{1/2}}{C^{1/3}D^3}$

$$\%\ \text{error},\ \frac{\Delta X}{X}\times 100 = 2\frac{\Delta A}{A}\times 100 + \frac{1}{2}\frac{\Delta B}{B}\times 100 + \frac{1}{3}\frac{\Delta C}{C}\times 100 + 3\frac{\Delta D}{D}\times 100$$

$$2 \times 1\% + \frac{1}{2} \times 2\% + \frac{1}{3} \times 3\% + 3 \times 4\%$$

= 2% + 1% + 1% + 12% = 16%